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Claire Océane CHEVALLIER
Born on 4th July 1986 in Paris (France)

FINANCIAL INTERMEDIATION AND MACROECONOMIC FLUCTUATIONS

Dissertation defence committee

Dr Henri Sneessens, dissertation supervisor
Professor, Université du Luxembourg

Dr Chiara Peroni, Vice-Chairman
National Institute of Statistics and Economic Studies of the Grand Duchy of Luxembourg (STATEC)

Dr Jean-Bernard Chatelain
Professor, Université Paris 1 Panthéon-Sorbonne

Dr Olivier Pierrard
Banque Centrale du Luxembourg

Dr Benteng Zou, Chairman
Associate Professor, Université du Luxembourg

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Abstract

The present dissertation explores the role of financial intermediation in generating, propagating and amplifying disruptions within the financial sector. It also discusses the role of banking regulation in the emergence and the collapse of banking bubbles.

Financial Shocks, External Finance, and Macroeconomic Fluctuations. The objective of this study is to investigate the macroeconomic effects of shocks originating within the financial sector and the role of firms' financial structure in the propagation of these shocks. It develops an extended RBC model, with financially constrained firms and an endogenous financial sector. Firms finance their investment either by borrowing from banks or by issuing new equity. The results suggest that financial shocks, represented by a sudden drop in the return on financial intermediaries' securities, generate a credit crunch and reduce firms' equity issuance. Financial shocks have stronger and more persistent impact on economic activity than shocks originating in the real economy. Financial contagion and credit constraints are key in explaining the amplification and the duration of financial shocks. As firms' funding falls, the availability of capital plummets so the credit constraint becomes tighter, and firms' demand for loans decreases. This slows down the recovery of the financial intermediation sector, and the economy as a whole. Empirical support for these findings is provided.

Empirical Investigation of the Effect of Bank Wholesale Debt on Loans and Output in the Euro-zone. This study explores the role of bank wholesale debt on loans and output in the Euro-zone between 1999 and 2014. It uses shocks to bank deposits and shocks to bank wholesale debt issuance as instruments in a linear two stage least square specification to evaluate the role of loan supply in affecting output. The findings show that banks' changed preferences for wholesale debt funding are important determinants of loan supply, in particular during the crisis. We also find evidence that loan supply

affects output significantly and positively. The validity of the model is also tested by verifying the linearity assumption using non-parametric estimation techniques.

Regulation and Rational Banking Bubbles in Infinite Horizon (joint with Dr. Sarah El Joueidi). We develop a dynamic stochastic general equilibrium model in infinite horizon with a regulated banking sector, where stochastic banking bubbles may arise endogenously. We analyze the conditions under which stochastic bubbles exist and their impact on macroeconomic key variables. We show that when banks face capital requirements based on Value-at-Risk, two different equilibria emerge and can exist: the bubbleless and the bubbly equilibria. Alternatively, under a regulatory framework where capital requirements are based on credit risk only, as in Basel I, bubbles are explosive and, as a consequence, cannot exist. The stochastic bubbly equilibrium is characterized by positive or negative bubbles depending on the tightness of capital requirements based on Value-at-Risk. We find a maximum value of capital requirements under which bubbles are positive. Below this threshold, and as long as the bubble stays, the stochastic bubbly equilibrium with positive bubbles provides larger welfare than the bubbleless equilibrium. In addition, our results suggest that a change in banking policies might lead to a crisis without external shocks.

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0. Introduction

The 2007-2009 U.S. subprime crisis led to the worst recession since World War II (IMF, 2009). It has highlighted the importance of the financial sector and its inadequate regulation in generating and propagating crises. Policy makers (Bernanke, 2010a) and researchers (Gertler et al., 2016; Gerali et al., 2010), impute recent events to disruptions in the banking sector. In particular, excessive leverage and financial innovation increased the banking sector's vulnerabilities (Basel Committee, 2010). In a speech to the Financial Crisis Inquiry Commission, the U.S. Federal Reserve's chairman, Bernanke (2010a), recognized that the system's vulnerabilities, and the deficient regulatory and policy tools available were crucial in explaining the severity of the last crisis.

Central bankers and policy makers failed to prevent the last financial crisis (Bernanke, 2010b). Mainstream models used in central banks and supervisory institutions (Smets and Wouters, 2007 for example) did not include an explicit financial sector element. Only recently have macroeconomic models incorporated the role of the banking sector, enabling studies of its role in the propagation and amplification of crises. de Walque et al. (2010), Gertler and Kiyotaki (2011) and Gertler and Kiyotaki (2011) are breakthrough macroeconomic models that incorporate an explicit banking market. The understanding of the role of financial intermediation in affecting macroeconomic performance is fundamental to designing solutions that are able to prevent future financial crises.

This work is built on the idea that the transmission mechanism and the macroeconomic consequences of shocks that affect banks are different from those that affect households or firms. While there is now well established literature on financial frictions in macroeconomics that focuses on the role of credit frictions in propagating real shocks (Bernanke et al., 1999; Kiyotaki and Moore, 1997; Carlstrom and Fuerst, 1997 and Iacoviello, 2005), the literature on the role of firms' financial structure in the propagation of shocks originating within the financial sector is scarce, thus calling for further research.

Recent studies have explored how bank wholesale funds affect economic activity, as the severity of the last financial crisis has been imputed to disruptions in the bank wholesale market (Gertler et al., 2016; Hanson et al., 2011). Wholesale funding, in contrast with retail deposits, is the most unstable source of funding of banks, and may therefore raise uncertainty, raising systemic risk. The wholesale banking sector includes inter-bank funding, and bank debt securities. The potential adverse effects due to bank reliance on wholesale funding is even greater in Europe, where banks have the highest share of wholesale funding in total liabilities, 61% of total liabilities on average, in comparison with Asia, emerging economies and the U.S. (Le Lesle, 2012). The literature has mostly focused on the role of the inter-bank market and short term wholesale debt in affecting economic activity. The understanding of the role of long term bank debt issuance on output has not been assessed, and this should help comprehend the contribution of variation in such funds in macroeconomic fluctuation. In particular, testing whether bank loan supply affects economic activity is an important question related to the understanding of the transmission mechanism of financial disturbances to the real economy. It requires dealing with large endogeneity issues. For example, identifying changes in loans that are not due to a change in output requires identification strategies.

How financial crises arise remain a challenging question. Miao and Wang (2015) argue that changes in agents' beliefs about stock market value of banks are suspected to explain sudden financial market crashes. The idea that the assets can be sold at their fundamental price is part of most economic analysis. Nevertheless, the crisis showed that prices can be severely distorted. Bubbles arising in the financial intermediation sector, in contrast with housing bubbles for example, may have large amplification effects (Brunnermeier and Oehmke, 2013). Moreover, works on the existence of bubbles in general equilibrium models with infinitely lived agents is marked with few important contributions (Miao, 2014). More research on asset price bubbles is needed (Bernanke, 2010b).

This dissertation contributes to the research on the role of financial intermediation in macroeconomic fluctuations. It investigates theoretically and empirically the effects of disruptions within the banking sector and the effects of bank lending on real economic activity. In particular, it explores the role of firms' financial frictions in propagating and amplifying shocks originating within the financial sector. It empirically evaluates the role of shocks to long term bank debt on economic activity. Finally, it studies how financial crises may arise, in particular how banking regulation may contribute to the emergence of bank asset price bubbles.

The first chapter studies the role of firms' financial structure and credit constraints in propagating shocks originating within the financial sector. It develops an extended real business cycle model, with an endogenous financial intermediation sector à la de Walque et al. (2010). Firms finance their investment either by borrowing from banks or by issuing new equity. They also face a credit constraint. The results suggest that financial shocks, represented by a sudden drop in the return on financial intermediaries' securities, generate a credit crunch and reduce firms' equity issuance. Financial shocks have a stronger and more persistent impact on economic activity than shocks originating in the real sector. Financial contagion and firms' credit constraints are key in explaining the amplification and the duration of financial shocks. As firms' funding falls, capital plummets, the credit constraint becomes tighter, firms' demand for loans decreases, all of which slows down the recovery in the financial intermediation sector, and therefore the whole economy. Empirical support for these findings is provided.

The second chapter is empirical. It explores the role of bank funding shocks on bank credit supply and output. Based on a linear specification, the study tests whether changes in bank credit, that are triggered by disruptions of bank wholesale funding, have significant effects on macroeconomic performance in the Euro-zone between 1999Q1 to 2014Q4. In addition, I verify the linearity assumption of the model by allowing non-linearities to arise, using non-parametric techniques. I show that changes in banks' preferences for wholesale debt funding are important determinants of loan supply, in particular during the crisis. I also find evidence that loan supply affects output significantly and positively. The linearity assumption in the bank lending channel, using country specific changes, is found to be adequate.

The third chapter develops a dynamic stochastic general equilibrium model in infinite horizon with a regulated banking sector, where stochastic bubbles on banks' asset prices may arise endogenously. It objective is to determine the regulatory conditions under which bubbles may exist and to evaluate the impact of bubbles on the macro-economy. We find that, when banks face capital requirements that account for market risk, that is, based on Value-at-Risk, two different equilibria emerge and can exist: the bubbleless and the bubbly equilibria. In contrast, when capital requirements are based on credit risk, as in Basel I, bubbles cannot exist. We show that positive or negative stochastic bubbles may arise, depending on the tightness of capital requirements based on Value-at-Risk. We find a threshold value of capital requirements below which bubbles are positive. Above this threshold, bubbles are negative. Before the bubble bursts, the stochastic bubbly equilibrium with a positive bubble provides larger welfare than the bubbleless equilibrium. Most importantly, our results suggest that a change in banking policies might lead to a crisis without external shocks.

1. Financial Shocks, External Finance, and Macroeconomic Fluctuations

1.1. Introduction

The 2007-2009 U.S. subprime crisis led to, in most developed countries, the worst recession since the World War II (IMF, 2009). Following these events, there was a large number of works studying the role of the financial sector in propagating and generating shocks (de Walque et al., 2010; Gertler and Kiyotaki, 2011). Empirical studies find that financial crises last longer and are deeper than ordinary recessions (Reinhart and Rogoff, 2009). It has been shown that the Euro-zone recession of 2008-2010 was largely due to shocks originating in the banking sector (Gerali et al., 2010). Yet, the propagation mechanism of disruptions within the financial sector - financial shocks - to the real sector is poorly understood. For instance, while there is now a well established literature on financial frictions in macroeconomics that focus on the role of credit frictions in propagating real shocks (Bernanke et al., 1999; Kiyotaki and Moore, 1997; Carlstrom and Fuerst, 1997; Iacoviello, 2005), the literature on their role in the propagation of financial shocks is scarce. The transmission mechanism and the macroeconomic consequences if banks are hit by a shock are different to shocks that affect households or firms. The understanding of the propagation mechanism of financial shocks is crucial to prevent future crises and build an adequate policy framework.

The objective of this chapter is to study the role of firms' financial structure in propagating shocks originating within the financial sector, *financial shocks*. This chapter develops an extended real business cycle (RBC) model, with an endogenous financial intermediation sector à la de Walque et al. (2010). Firms can choose between bank credit and equity financing.

de Walque et al. (2010), Gertler and Kiyotaki (2011) and Gertler and Kiyotaki (2011) are the breakthrough and seminal studies that incorporate an explicit inter-bank market. de Walque et al. (2010) build a dynamic general equilibrium model with a heterogeneous financial sector, possibility of default for firms and banks, and shocks to profits in the financial intermediation sector. They introduce an inter-bank market to analyze the role of this market in business fluctuations and liquidity issues. They are able to reproduce key U.S. business cycles moments. They also study the role of endogenous default in generating financial accelerators. Finally, monetary and policy analyses (Basel I and II) are carried out. They find that Basel II requirements exacerbate financial crises.

Gertler and Kiyotaki (2011) build a model in which banks can be financed through wholesale inter-bank deposits in addition to retail deposits. There are agency problems that lead to endogenous constraints for intermediaries in collecting retail deposits. Their model incorporates a financial accelerator à la Bernanke et al. (1999) but applied to a heterogeneous financial intermediation sector. It corresponds to amplifications due to balance sheet effects in the presence of credit frictions. Their key contribution is twofold. First, they have, to some extent, reproduced quantitatively the facts from the last financial crisis. They show quantitatively that a financial accelerator in the financial sector itself played a large role in the recent contraction of the U.S. economy. Second, they have developed a model that shows that financial intermediation can amplify disturbances to the real economy.

Gertler et al. (2012) build on Gertler and Kiyotaki (2011), but go one step further by developing a model in which balance sheet risk is chosen endogenously by financial intermediaries. They are able to explain why banks opt for risky balance sheets and how it, in turn, affects real economic outcomes. Their focus is on the role of credit policy in mitigating financial crises.

The three last cited models emphasize the role of the inter-bank market in amplifying financial shocks. Nevertheless, they do not study the role of firms' financial structure in the transmission of such disruptions. Firms' financial structure may play an important role in the transmission of financial shocks.

Jermann and Quadrini (2012) develop an extended RBC model in which firms' financial structure matters for business cycles and the transmission of shocks. Firms can choose between debt and equity. They face a collateral constraint when borrowing from the financial sector. They find that exogenous shocks to the tightness of the collateral constraint can explain the cyclicality of firms' aggregate debt and equity over the business cycle. They also show how firms' credit frictions can have negative consequences on the demand for labor. However, there are no frictions in the financial intermediation sector and thus, banks play no role in the amplification of shocks. The collateral constraint insures financial intermediaries and therefore deposit holders against risk. Hence, a tighter credit constraint leads firms to substitute debt for equity. Indeed, Jermann and Quadrini (2012) find that firms issue more equity and less debt in times of crisis. However, financial crises can spread to cause asset market stress (Gilchrist and Zakrajsek, 2012), and it may be too costly for firms to substitute debt for equity. The empirical literature on aggregate debt and equity (Covas and Den Hann, 2011; Covas and Den Haan, 2012; Levy and Hennessy, 2007; Korajczyk and Levy, 2003; Choe et al., 1993) agrees on the fact that firms that are most constrained financially issue less equity in bad economic environments. Only Jermann and Quadrini (2012) document that firms net equity issuance is counter-cyclical.

This chapter develops a model in which firms' and banks' financial frictions can interact to propagate financial shocks. The model incorporates a government, a representative firm, a representative household and an endogenous banking sector à la de Walque et al. (2010). By using bank default, de Walque et al. (2010) introduce a simple way of incorporating frictions into the financial sector. Therefore, their model includes the main inter-bank market characteristics while keeping the mechanisms tractable. In addition to bank credit, the firm can be financed through equity issuance. It also faces an enforcement constraint when borrowing from the bank. This allows to analyze the role of firms external financing constraints in propagating disruptions originating within the financial intermediation sector. The role of such frictions in propagating financial shocks may be different to their role in propagating crises originating in the real sector.

The model is able to reproduce key facts of the last financial depression and key business cycle properties. Firms' financial structure and credit constraints are able to explain how financial shocks trigger a decrease in inter-bank lending, and counter-cyclical labor. Shocks in the financial intermediation sector generate recessions that are stronger and last longer than ordinary ones. Reinhart and Rogoff (2009), Boissay et al. (2016) and Caldara et al. (2013) find similar results. Equity issuing is found to be pro-cyclical for financially constrained firms, as in most of the literature on firms' cyclicality of debt issuance. Furthermore, results show that capital adjustment costs dampen the adverse effects on output of negative productivity and financial shocks. The impact of counter-cyclical capital buffers for banks, as in Basel III regulation, on the economy is also analyzed. Results show that the counter-cyclicality of buffers, as in Basel III, can help mitigate financial crises.

The remainder of the chapter is as follows. In Sections 1.2 and 1.3, the model and its equilibrium are given. Section 1.4 displays the calibration of parameters. Section 1.5 discusses how financial shocks are propagated to the economy when firms' funds are imperfectly substitutable. Section 1.6 discusses some moments implied by the model. Section 1.7 analyses the impact of Basel III requirement on the economy. Some discussion on the model assumptions and sensitivity analyses are then presented. A conclusion is presented in the last section.

1.2. Model

The model developed in this chapter includes risk neutral firms, risk averse households, two risk averse banks, and a government. Financial intermediaries are modeled according to de Walque et al. (2010). There is one bank, called the merchant bank that lends to firms and in turn borrows from the second bank, called the lending bank. The lending bank collects retail deposits from households. Banks are subject to regulatory requirements regarding their balance sheet, as in Basel accords. The model assumes that the merchant bank has the possibility to default on its inter-bank borrowings. The lending bank cannot default. This is justified by the fact that, at least in OECD countries, deposits are guaranteed. Firms maximize their profits using labor, capital, equity and debt. They face a collateral constraint when borrowing from merchant banks. Households are shareholders of firms, debt holders of the lending bank, and supply labor to firms. The government collects taxes from households and plays the role of an insurance fund for banks. For simplicity, it also represents the supervisory authority that sets the bank capital requirements and the default costs.

1.2.1. Firms

Firms are endowed with a production technology $F(z_t, k_t, n_t) = z_t k_t^{\eta} n_t^{1-\eta}$, $0 < \eta < 1$. Production is realized at the end of time t. The variable z_t is the stochastic level of productivity. It is known at the beginning of the time interval t, before the production is realized. The variable k_t is the stock of capital and is chosen at time t-1, and the variable n_t is labor, chosen at the beginning of the time interval t. The price of output is normalized to 1. Labor payments are w_t.

Investment expenditure can be financed by issuing new equity $d_t < 0$ or, by borrowing from banks L_{t+1}.[1] Dividend payments ($d_t > 0$) or new equity issues ($d_t < 0$) are decided at the beginning of t, that is, when the realized value of the productivity shock is known but production has not taken place yet. The incentive for bank debt financing arises from a tax advantage and a cost from issuing new equity. Firms pay interest $R_t = 1 + r_t^b(1 - \tau)$ on debt, where τ is the tax advantage over the real interest rate r_t^b on firms' loans. Indeed, interest on debt is often tax deductible, unlike dividends. The assumption on the tax advantage ensures that firms' financial constraints are binding by letting firms have a preference for debt. It has many theoretical motivations. For example, it is usually less costly to raise debt than new equity since raising debt does not dilute the ownership structure of the firm. Some authors have also showed that debt is less costly than new outside equity because of legal or accounting reasons.[2]

Firms equity payout adjustment costs are $\kappa \left(d_t - \bar{d}\right)^2$, where $\bar{d}$ is the equity payout long term value. The cost need not be interpreted as a pecuniary cost. It can be interpreted as the preference managers have for dividend smoothing (it is costly to deviate from the steady state value) or the speed at which firms can substitute equity for debt when the financial conditions, represented by the parameter κ, change. This is consistent with observations made by Lintner (1956) and later confirmed by recent empirical and survey evidence.[3] Indeed, Lintner (1956) shows that dividend payout policy is a function of the firm's current profits scaled by a long term target payout ratio.

Because production is only available at the end of the period t, after employment and investment expenses have to be paid, firms borrow $l_{i,t} = F(z_t, k_t, n_t)$ from the financial intermediary and are subject to a constraint on these lend-

[1] As in Jermann and Quadrini (2012), d_t is defined as net dividend payouts (= sum of share repurchases and dividends minus equity issues). It is interpreted as new equity issues if $d_t < 0$.

[2] See Narayanan (1988).

[3] Michaely and Roberts (2012), Lambrecht and Myers (2012) and Brav et al. (2005).

ings.[4] The financial intermediary is repaid at the end of the same period and without interest, after production has occurred. This intra-temporal debt can be understood as a shortcut to the fact that firms carry cash from one period to the next. As in Jermann and Quadrini (2012), the firm can decide to default on its intra-period loan. If the firm decides to default, there is a probability ξ_t that the lender can recover the whole value of the collateral, and a probability 1-ξ_t that the lender cannot recover anything. In the remainder of this chapter, these probabilities are assumed stochastic. They reflect unspecified market conditions. Changes in their values will be referred to as *liquidity shocks*, indicating that firms' liquid funds l_t can be easily diverted. An enforcement constraint is set by the financial intermediary to ensure that, the firm's expected value of defaulting does not exceed its expected value of not defaulting. It limits the acquisition value of capital to a weighted average of the total debt of the firm such that $F\left(z_t, k_t, n_t\right) + \xi_t L_{t+1}/\left(1+r_t^b\right) \leq \xi_t k_{t+1} q_{t+1}$,[5] where q_{t+1} can be interpreted as the Tobin's_q. Note that liquidity and productivity shocks are common to all firms. The study can thus concentrate on a representative firm.

It is furthermore assumed that there are convex adjustment costs to capital, $\phi/2(I_t/k_t - \delta)^2 k_t$. The variable I_t corresponds to capital investment. The parameter ϕ is a scaling factor representing the size of the adjustment costs. Capital adjustment costs imply that there are increasing marginal costs in capital production, capturing the idea that firms want to smooth capital investment over time. It is thus more costly to vary capital by a great deal than by a small amount.

The entrepreneur maximizes the firm's current value subject to its budget constraint and an enforcement constraint. The firm's current value, which is the ex dividend price of the firm, depends on the sequence of future payoffs (dividends), discounted by the household stochastic discount factor, m_{t+j}. This shareholder's problem, maximizing the value of future cash flows, coincides with the stakeholder's problem, as the shareholder is also the final consumer, the employee, and the household:

[4] The firm borrows the amount that it will be able to reimburse, $l_{i,t} = F(z_t, k_t, n_t)$. Not less otherwise production and profits will be lower, not more otherwise, the firm cannot reimburse.

[5] See Jermann and Quadrini (2012) for further details on the enforcement constraint.

$$Max_{\{d_t,n_t,k_{t+1},I_t,L_{t+1}\}_{t=0}^{\infty}} E_0 \left[\sum_{j=1}^{\infty} m_{t+j} d_{t+j} \right],$$

subject to

$$F(z_t, k_t, n_t) + \frac{L_{t+1}}{R_t} = w_t n_t + I_t + \psi(d_t) + L_t + \frac{\phi}{2} \left(\frac{I_t}{k_t} - \delta \right)^2 k_t, \tag{1.2.1}$$

$$F(z_t, k_t, n_t) \leq \xi_t \left(k_{t+1} q_{t+1} - \frac{L_{t+1}}{1 + r_t^b} \right), \tag{1.2.2}$$

$$I_t = k_{t+1} - (1 - \delta) k_t, \tag{1.2.3}$$

$$\psi(d_t) = d_t + \kappa \left(d_t - \overline{d} \right)^2, \tag{1.2.4}$$

$$R_t = 1 + r_t^b (1 - \tau). \tag{1.2.5}$$

Write λ_t the Lagrangian multiplier of the budget constraint (1.2.1), μ_t the one associated with the enforcement constraint (1.2.2), and q_t the multiplier of the investment constraint (1.2.3). The first order conditions with respect to d_t, k_{t+1}, I_t, L_{t+1}, and n_t yield, in the interior solution, the equations:[6]

$$\lambda_t = \frac{1}{\psi_{d_t}}, \tag{1.2.6}$$

$$\begin{aligned} q_t = E_t \{ &\frac{m_{t+1}}{m_t} \frac{\psi_{d_t}}{\psi_{d_{t+1}}} [F_{k_{t+1}} (1 - \mu_{t+1} \psi_{d_{t+1}}) + q_{t+1} (1 - \delta) \\ &+ \frac{I_{t+1}}{k_{t+1}} \phi (\frac{I_{t+1}}{k_{t+1}} - \delta) - \frac{\phi}{2} (\frac{I_{t+1}}{k_{t+1}} - \delta)^2] + \xi_t \mu_t \psi_{d_t} q_{t+1} \}, \end{aligned} \tag{1.2.7}$$

$$q_t = 1 + \phi \left(\frac{I_t}{k_t} - \delta \right), \tag{1.2.8}$$

$$1 = R_t E_t \left\{ \frac{m_{t+1}}{m_t} \frac{\psi_{d_t}}{\psi_{d_{t+1}}} \right\} + \mu_t \psi_{d_t} \xi_t \frac{R_t}{1 + r_t^b}, \tag{1.2.9}$$

[6] $\psi_{d_t} = \partial \psi(d_t) / \partial d_t$.

$$F_{n_t} = w_t \left[\frac{1}{1 - \mu_t \psi_{d_t}} \right]. \tag{1.2.10}$$

Condition (1.2.6) shows that, in an interior solution, raising one more unit of dividends must equal the marginal cost from raising dividends.

Equation (1.2.7) shows that the marginal value today of an additional unit of capital k_{t+1}, q_t, must equal the discounted value of future marginal benefits from capital plus the marginal benefit from relaxing the enforcement constraint.

Condition (1.2.8) displays demand for capital as a function of the shadow value of investment q_t. It reveals that investment in capital is a positive function of the marginal value of an additional unit of capital, q_t.

The demand for inter-temporal loans is displayed by (1.2.9). In an interior solution, borrowing one more unit from banks must equal the discounted lending rate, weighted by the dividend marginal costs plus the cost of raising the tightness of the enforcement constraint. Taking prices r_t^b and R_t as given, (1.2.9) shows that a fall in the firm's collateral value ξ_t, tightens the enforcement constraint. From (1.2.9) in the stationary steady state, defined by $x_t = x_{ss}$ for all t, if $\tau > 1 - (1 - \beta) / \beta r^b$, the net interest rate paid on loans is smaller than the one paid on stocks.[7]

The equality (1.2.10) displays how firms' financial structure affects labor demand. Indeed, both dividend marginal costs and the firm's credit constraint tightness impact the demand for labor. The larger are the marginal costs associated with increasing one unit of each type of financing, the larger must be the marginal benefit from raising one unit of labor. Intuitively, to see how firms' financial structure changes the demand for labor, assume there are no capital adjustment costs, $\phi = 0$, and use the budget constraint to rewrite the enforcement constraint (1.2.2) as:

$$\frac{\xi_t}{1 - \xi_t} \left[(1 - \delta) k_t - w_t n_t - \psi(d_t) - L_t \right] \geq F(z_t, k_t, n_t). \tag{1.2.11}$$

Suppose the enforcement constraint is binding. At the beginning of the period the numbers k_t and L_t are given. Given a level of inter-period loans L_{t+1}, a negative productivity shock reduces the tightness of the constraint. As a consequence labor demand and dividend payouts rise. If, the required dividend payout rises for reasons that are exogenous to the firm constraint (an increase

[7] Hence, the enforcement constraint binds for large enough values of tax benefit.

in risk on financial markets for example, such that households discount the future more heavily, $\beta' < \beta$), labor demand decreases.

1.2.2. Banking sector

Financial frictions on financial markets are introduced as in de Walque et al. (2010). There are two distinct representative banks, the merchant bank and the lending bank. Banks can make balance sheet decisions. The merchant bank borrows on the inter-bank market, W^b_{t+1}, and decides how much to lend to firms, L_{t+1}, taking as given the interest rate, r^b_t. The lending bank collects deposits from households, D_{t+1}, and lends on the inter-bank market, W^l_{t+1}, at an interest rate i_t. Retail deposits are remunerated at a rate r^l_t. Both financial intermediaries receive payments from exogenous investment in securities B^i_t, $i = b, l$. For convenience, it is assumed that $B^i_t = B$ for $i = b, l$. In each period t, there is a constant fraction $1 - v_i$, $i = b, l$, of profits that are consumed and a fraction v_i that are used to increase buffer capital F^i_t, $i = b, l$.

A risk of default is introduced by assuming that the merchant bank can choose to default and repay a fraction θ_{t+1} of its total debt W^b_t with the lending bank. The risk of default introduces financial frictions within the banking sector. Therefore, banks may contribute to the propagation of shocks. They do not only intermediate funds from households to firms. When the bank defaults, it pays a pecuniary cost on the defaulted amount, $\omega_b \left[(1 - \theta_t)\, W^b_{t-1}\right]^2$, the period after having defaulted. It can be interpreted as a cost to find new credit. Both banks are also subject to a market book shock, i.e. the financial shock, affecting the return on securities ρ_t. The financial sector is thus characterized by financial fragility from default and reduced bank profitability. Reduced profitability in the banking sector can, in turn, affect real economic activity by reducing loan supply. To alleviate such mechanism, the insurance fund is a macro-prudential mechanism that requires both banks to pay a fraction, respectively ζ_b and ζ_l, of their buffer capital F^i_t, $i = b, l$, to an insurance fund. The insurance fund then returns a fraction τ^l of the total amount the merchant bank failed to reimburse last period. The merchant bank is subject to a capital requirement constraint

$$F^b_{t+1} \geqslant k_{rr,t} \left(\varpi L_{t+1} + \widetilde{w} B^b\right).$$

Similarly, the lending bank is subject to $F^l_{t+1} \geqslant k_{rr,t} \left(\overline{\varpi} W^l_{t+1} + \widetilde{w} B^l\right)$. Lendings

L_{t+1}, W^l_{t+1} and market book securities B^i_t, $i = b, l$ are considered by the authority to be risky assets and are assigned weights $\overline{\omega}$, $\overline{\overline{\omega}}_{t+1}$ and $\widetilde{w}$. Banks are required to hold a minimum fraction k_{rr} of their risky assets as buffer capital. The minimum capital requirement is set by the authority and weights are defined by the Basel accords.

Each bank's objective is to maximize its expected inter-temporal utility, subject to its budget constraint and the accumulation of buffer capital constraints. Their utility increases in their profits π^i_t, $i = b, l$, in the cushion of buffer capital, and decreases in a non pecuniary cost, $d_b\,(1 - \theta_{t+1})$ for the merchant bank only.[8] This non pecuniary cost, $d_b\,(1 - \theta_{t+1})$ can be interpreted as a disutility from reputation loss of defaulting. Respectively, write λ^i_t and γ^i_t, $i = b, l$, the shadow value of profits and the shadow value of banks' buffer capital accumulation. The variables λ^i_t, $i = b, l$, are the prices, in dollars per unit of consumption, the bank would pay for increasing the capacity of the production by one unit in order to increase its profits. The variables γ^i_t, $i = b, l$, represent the price the bank would pay for increasing banks' buffer capital by one unit.

The Merchant Bank

The merchant bank optimization problem is to choose $\left\{W^b_{t+1}, L_{t+1}, \theta_{t+1}, \pi^b_t, F^b_{t+1}\right\}^{\infty}_{t=0}$ in order to maximize its expected lifetime utility, subject to its constraints:[9]

$$Max_{\left\{W^b_{t+1}, L_{t+1}, \theta_{t+1}, \pi^b_t, F^b_{t+1}\right\}^{\infty}_{t=0}} \sum_{t=0}^{\infty} E_t\beta^t\{ln\left(\pi^b_t\right) - d_b\,(1 - \theta_{t+1}) \\ + d_{F^b}\left[F^b_{t+1} - k_{rr,t}\left(\overline{\omega}L_{t+1} + \widetilde{\omega}B^b\right)\right]\},$$

subject to

$$F^b_{t+1} = (1 - \zeta_b)\,F^b_t + v_b\pi^b_t, \tag{1.2.12}$$

[8]The assumption that there is a non pecuniary cost of defaulting allows the avoidance of indeterminacy.

[9]The term $1 - v_i > 0$, $i = b, l$ is omitted when maximizing the consumption of the bank because $ln\left[(1 - v_i)\,\pi^i_t\right] = ln\,(1 - v_i) + ln\pi_t{}^i$. The constant term $1 - v_i$ disappears because the model is linearized.

$$\pi_t^b = L_t + \frac{W_{t+1}^b}{1+i_t} - \theta_{t+1} W_t^b - \frac{L_{t+1}}{1+r_t^b} - \frac{\omega_b}{2}\left[(1-\theta_t) W_{t-1}^b\right]^2 + \rho_t B^b. \quad (1.2.13)$$

The first order optimality conditions with respect to θ_{t+1}, W_{t+1}^b, L_{t+1}, F_{t+1}^b, and π_t^b yield:

$$\lambda_t^b W_t^b = E_t\left[\beta \lambda_{t+1}^b \omega_b (1-\theta_{t+1}) W_t^{b2} + d_b\right], \quad (1.2.14)$$

$$\frac{\lambda_t^b}{1+i_t} = E_t\left[\beta \theta_{t+2} \lambda_{t+1}^b + \beta^2 \omega_b \lambda_{t+2}^b (1-\theta_{t+2})^2 W_{t+1}^b\right], \quad (1.2.15)$$

$$\frac{\lambda_t^b}{1+r_t^b} = E_t\left[\beta \lambda_{t+1}^b - d_{F^b} k_{rr,t} \overline{\omega}\right], \quad (1.2.16)$$

$$d_{F^b} = \gamma_t^b - E_t\left[\beta (1-\zeta_b) \gamma_{t+1}^b\right], \quad (1.2.17)$$

$$\gamma_t^b = \frac{1}{\upsilon_b}\left(\lambda_t^b - \frac{1}{\pi_t^b}\right). \quad (1.2.18)$$

The optimality condition (1.2.14) shows that, in an interior solution, the marginal pecuniary gain from defaulting must be equal to its marginal cost. The marginal cost from defaulting includes a pecuniary and a non pecuniary cost. Thus, as long as there is a disutility from defaulting, $d_b > 0$, there is a strictly positive pecuniary gain from defaulting at the margin.

Condition (1.2.15) establishes the demand for wholesale inter-bank borrowing W_{t+1}^b. At the optimum, the marginal benefit from inter-bank borrowing must equal its discounted marginal cost.

From (1.2.14), an increase in default raises the tightness of the profit constraint, thereby increasing the demand for inter-bank loans (see (1.2.15)). Particulary, combining (1.2.14) and (1.2.15) and considering the stationary steady state for simplicity, such that $x_t = x_{t+1} = x$ for all t, $1/(1+i) = \beta\left(1 - d_b(1-\theta)/\lambda^b W^b\right)$. Therefore, the demand for inter-bank loans is negatively sloped and the slope becomes larger with the default.

The supply of loans is given by (1.2.16). Taking prices as given, r_t^b, it shows that the minimum capital requirement regulation $k_{rr,t}$ is negatively related to the tightness of the constraint λ_t^b. If the regulatory constraint becomes more lenient, banks can supply more loans, making the budget constraint tighter.

Equation (1.2.17) establishes the demand for buffer capital. It shows that the merchant bank's shadow value of accumulating buffer capital is strictly postie only if the utility from deriving a cushion of buffer capital above the minimum requirement is positive, $d_{F^b} > 0$. It is also worth noting that the insurance cost ζ_b changes the inter-temporal arbitrage condition of holding buffer capital.

Equation (1.2.18) shows that the bank's marginal benefit from an additional unit of profit is equal to, in an interior solution, the price, in dollars per unit of consumption, the bank would pay to increase the capacity of production by one unit. The marginal benefit from an additional unit of profits equals the marginal utility the bank derives plus the shadow value of the bank's buffer capital resulting from the increase in buffer capital.

Then, combining (1.2.14), (1.2.15) and (1.2.16),

$$\frac{1+r_t^b}{1+i_t} = \frac{E_t\left[1 - \frac{d_b}{\beta\lambda_{t+1}^b W_{t+1}^b}\beta\left(1-\theta_{t+2}\right)\right]}{E_t\left[1 - \frac{d_{F^b} k_{rr,t}\overline{\omega}}{\beta\lambda_{t+1}^b}\right]}.$$

The merchant bank's disutility of defaulting d_b and utility of satisfying the capital requirement d_{F^b} introduce a wedge between the lending rate to the firm r_t^b and the borrowing rate i_t on inter-bank wholesale funds. These wedges are amplified with tighter capital requirements $k_{rr,t}$. Indeed, the tighter the regulatory constraint is, the less the bank can lend and the larger the lending rate r_t^b is. In addition, by raising the inter-bank rate, default reduces the interest rate wedge.

The Lending Bank

The lending bank problem is to choose $\left\{W_{t+1}^l, D_{t+1}, \pi_t^l, F_{t+1}^l\right\}_{t=0}^{\infty}$ to maximize its expected lifetime utility, subject to its constraints:

$$Max_{\left\{W_{t+1}^l, D_{t+1}, \pi_t^l, F_{t+1}^l\right\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} E_t\beta^t \left\{ln(\pi_t^l) + d_{F^l}\left[F_{t+1}^l - k_{rr,t}\left(\overline{\overline{\omega}}_t W_{t+1}^l + \widetilde{\omega} B^l\right)\right]\right\},$$

subject to

$$F_{t+1}^l = \left(1-\zeta_l\right)F_t^l + \upsilon_l \pi_t^l, \qquad (1.2.19)$$

$$\pi_t^l = \theta_{t+1} W_t^l + \frac{D_{t+1}}{1+r_t^l} - D_t - \frac{W_{t+1}^l}{1+i_t} + \tau^l \left(1-\theta_t\right) W_{t-1}^l + \rho_t B^l. \qquad (1.2.20)$$

The interior solutions given the optimality conditions with respect to D_{t+1}, W_{t+1}^l, F_{t+1}^l, and π_t^l are:

$$\frac{\lambda_t^l}{1+r_t^l} = \beta E_t \lambda_{t+1}^l, \qquad (1.2.21)$$

$$\frac{\lambda_t^l}{1+i_t} = E_t \left[\beta \theta_{t+2} \lambda_{t+1}^l + \beta^2 \tau^l \lambda_{t+2}^l \left(1-\theta_{t+2}\right) - d_{F^l} k_{rr,t} \overline{\overline{w}}_t\right], \qquad (1.2.22)$$

$$d_{F^l} = \gamma_t^l - E_t \left[\beta \left(1-\zeta_l\right) \gamma_{t+1}^l\right], \qquad (1.2.23)$$

$$\gamma_t^l = \frac{1}{v_l} \left(\lambda_t^l - \frac{1}{\pi_t^l}\right). \qquad (1.2.24)$$

The first order condition (1.2.21) displays the demand for deposits from the lending bank. In an interior solution, the inter-temporal rate of marginal substitution must equate the marginal cost of borrowing D_{t+1}. The supply of inter-bank loans is given by (1.2.22). The marginal cost from lending W_{t+1}^l, which includes the cost from reducing the cushion of buffer capital, must equal its marginal benefit. The marginal benefit includes the insurance compensation, through τ^l, and the net return from lendings. The conditions (1.2.23) and (1.2.24) are interpreted as in the problem faced by the merchant bank.

Neglecting the uncertainty, the combination of (1.2.21) and (1.2.22) yields the interest rate spread between the borrowing rate r_t^l and the lending rate i_t for the lending bank:

$$\frac{1+i_t}{1+r_t^l} = \frac{1}{1 - \left(1 - \beta \tau^l \frac{\lambda_{t+2}^l}{\lambda_{t+1}^l}\right) \left(1-\theta_{t+2}\right) - \frac{d_{F^l} k_{rr,t} \overline{\overline{w}}_t}{\beta \lambda_{t+1}^l}}.$$

Similarly to the merchant bank, the utility from the safety regulatory cushion d_{F^l} introduces a wedge between the lending rate to firms and the retail deposit rate. Furthermore, bank default $1-\theta_{t+2}$ increases the interest rate spread. However, insurance compensation τ^l reduces the impact from default.

Altogether, abstracting from uncertainty, the interest spread resulting from the inter-bank frictions is:

$$\begin{aligned} r_t^b - r_t^l &= \frac{d_{F^b} k_{rr,t} \overline{\omega}}{\beta \lambda_{t+1}^b} + \left(1 - \beta \tau^l \frac{\lambda_{t+2}^l}{\lambda_{t+1}^l}\right)(1 - \theta_{t+2}) \\ &+ \frac{d_{F^l} k_{rr,t} \overline{\overline{w}}_t}{\beta \lambda_{t+1}^l} - \frac{d_b}{\beta \lambda_{t+1}^b W_{t+1}^b} \beta (1 - \theta_{t+2}). \end{aligned}$$

The lending bank's total cost from defaulting net of the insurance compensation and the non-pecuniary cost of default, plus the utility derived from the banking regulation cushion generate a wedge between the rate at which the lending bank borrows funds from households, and the rate at which the merchant bank lends to firms.

Banks' minimum capital requirements are key components in the amplification mechanism of financial shocks described above. This is because they determine the degree of inter-bank financial frictions, the degree to which banks' supply and demand for funds reacts to shocks, and thereby, the extent of change of loans to firms. An increase in capital requirements of banks, $k_{rr,t}$, increases the marginal cost of inter-bank lending which reduces available funds for the merchant bank and therefore, loans to firms. Since firms funds are imperfectly substitutable, investment and output should be affected. As a consequence, pro-cyclical weight**s** on risky assets $k_{rr,t}$ are expected to amplify shocks through their negative effect on credit, while counter-cyclical capital buffers (such as in Basel III) are expected to dampen adverse financial shocks.

1.2.3. Households

There is a continuum of infinitely lived homogeneous households.[10] Given their labor income w_t, the deposits D_t they receive back from last period savings, their net payout from owning shares d_t and the market price p_t from selling their share, households choose how much stock to hold in each period s_{t+1} and how many hours to work n_t, pay taxes T_t, consume c_t, and decide how much deposits to hold until the next period D_{t+1}. The variable r_t^l is the interest rate gained from t to $t+1$ by depositing money into the lending bank. The household

[10]To simplify the model, it is assumed that the continuum of identical households are of mass one. Thus, the infinity of households is equivalent to a single representative household. This is a standard assumption in the general equilibrium macroeconomic literature.

maximizes its expected lifetime utility, subject to its budget constraint:

$$Max_{\{c_t, D_{t+1}, s_{t+1}, n_t\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t E_t \left[U\left(c_t, n_t, D_{t+1}\right)\right],$$

subject to

$$w_t n_t + D_t + s_t \left(p_t + d_t\right) = \frac{D_{t+1}}{1 + r_t^l} + c_t + T_t + s_{t+1} p_t. \qquad (1.2.25)$$

The household utility is a positive function of deposits, because of the transactions services they provide as a means of payment. It is logarithmic in consumption and leisure time. The utility function is written as $U\left(c_t, n_t, D_{t+1}\right) = ln\left(c_t\right) + \vartheta ln\left(1 - n_t\right) - \chi/2\left[D_{t+1}/\left(1 + r_t^l\right) - \overline{D}/\left(1 + r^l\right)\right]^2$.[11] The number χ corresponds to the money varying disutility term. The parameter ϑ is the weight assigned to leisure.

The variable λ_t^H corresponds to the shadow value associated with relaxing the budget constraint. At an interior solution, the first order conditions with respect to c_t, n_t, D_{t+1}, s_{t+1} are

$$\lambda_t^H = \frac{1}{c_t}, \qquad (1.2.26)$$

$$w_t = \frac{\vartheta c_t}{1 - n_t}, \qquad (1.2.27)$$

$$\lambda_t^H \frac{1}{1 + r_t^l} = \beta E_t \lambda_{t+1}^H - \chi E_t \left(\frac{D_{t+1}^l}{1 + r_t^l} - \frac{\overline{D}^l}{1 + r^l}\right) \frac{1}{1 + r_t^l}, \qquad (1.2.28)$$

$$p_t = \beta E_t \frac{\lambda_{t+1}^H}{\lambda_t^H} \left(d_{t+1} + p_{t+1}\right). \qquad (1.2.29)$$

Equation (1.2.26) shows that the marginal cost of raising consumption must equal the marginal utility from it. Equation (1.2.27) is the household intratemporal condition between consumption and leisure, and gives the optimal labor supply. Equation (1.2.28) gives the inter-temporal optimum condition of the household. Assume for simplicity that $\chi = 0$, then the present value of consumption tomorrow, weighted by the discount factor $\beta < 1$ is equal to consumption today. As displayed in (1.2.28), the marginal disutility of deposits

[11] For example, including money in the utility function has been done by Obstfeld and Rogoff (1996) and Sidrauski (1967).

affects the inter-temporal decision of households. As in de Walque et al. (2010), χ is set to be very small, and the steady state of deposits is calibrated to the data.

Condition (1.2.29) yield the demand for shares. The combination of (1.2.28) and (1.2.29) gives the household no arbitrage condition, $E_t\left(d_{t+1}+p_{t+1}\right)/p_t = 1+r_t^l$. This equality shows that, in an interior solution, where households invest in both shares and deposits, the expected marginal return of buying shares, $E_t\left(d_{t+1}+p_{t+1}\right)/p_t$, must be equal to the marginal return on deposits, $1+r_t^l$.[12]

Finally, the firm's optimization problem is consistent with the problem of households if the following equality holds:[13]

$$m_{t+j} = \beta^j \frac{U_{c_{t+j}}}{U_{c_t}}. \tag{1.2.30}$$

It shows that the firm must discount future payoffs with the household stochastic discount factor.

1.2.4. Government

The government collects the insurance fund from both banks (ζ_b and ζ_l) and taxes from households T_t to pay for the amount the lending bank recovers from the merchant bank default (through τ^l), and to finance the tax advantages on debt to the firm. Government purchases are null. Its revenue is equal to its transfers.

$$T_t + \zeta_b F_t^b + \zeta_l F_t^l = \tau^l\left(1-\theta_t\right) W_{t-1}^l + \frac{L_{t+1}}{1+r_t^b\left(1-\tau\right)} - \frac{L_{t+1}}{1+r_t^b}.$$

1.2.5. Regulation

The regulatory authority sets the respective weights $\overline{\omega}$, $\overline{\overline{\omega}}_{t+1}$ and $\widetilde{w}$ assigned to lending to firms, L_{t+1}, inter-bank lending W_{t+1}^l and the market books B^i, $i=b,l,$. They are constant under the Basel I accords. Under the Basel II accords these are endogenous variables, depending on the risks taken by banks. Basel III accords extend Basel II by increasing the number of assets to put in the coverage ratio of risky assets above the minimum capital requirement and

[12] If one was higher than the other one, households would only hold the one with the highest return.

[13] This is calculated by forward substitution of (1.2.29).

by incorporating a capital buffer (between 0 and 2.5 %) that is larger in good times than in bad times.[14] It also tightens the capital requirement constraint by requiring banks to hold a larger amount of capital in good times. As in de Walque et al. (2010), under Basel II accords, it is assumed $k_{rr,t} = k_{rr}$ and

$$\bar{\bar{\omega}}_t = \bar{\bar{\omega}} E_t \left(\frac{\theta}{\theta_{t+2}} \right)^{\eta^l}, \tag{1.2.31}$$

where $\eta^l > 0$. Then, define $y_t = F(z_t, k_t, n_t)$. Under Basel III weights are subject to (1.2.31). Additionally, there is a counter-cyclical buffer:[15]

$$k_{rr,t} = k_{rr} E_t \left[1 + \left(ln \frac{y_t}{y_{ss}} \right)^{\eta^k} \right] \tag{1.2.32}$$

where the parameter $\eta^k > 0$.

1.2.6. Shocks

As mentioned, there are three types of shocks in this economy. There is a productivity shock on firms' production z_t, a shock to the probability ξ_t the merchant bank can recover the collateral value in case of default of firms, and a shock to the return on banks' market book assets ρ_t. The process for financial shocks is taken from de Walque et al. (2010) while the liquidity shocks and the productivity shocks follow Jermann and Quadrini (2012) estimation. The shock processes are summarized in the auto regressive system:

$$\begin{pmatrix} \widehat{z}_{t+1} \\ \widehat{\xi}_{t+1} \\ \widehat{\rho}_{t+1} \end{pmatrix} = A \begin{pmatrix} \widehat{z}_t \\ \widehat{\xi}_t \\ \widehat{\rho}_t \end{pmatrix} + \begin{pmatrix} u^z_{t+1} \\ u^\xi_{t+1} \\ u^\rho_{t+1} \end{pmatrix},$$

where $\widehat{x}_{t+1}$ are log deviations from their respective steady state values, u^z_{t+1}, u^ξ_{t+1}, and u^ρ_{t+1} are normally distributed, i.i.d.

1.3. Equilibrium

An equilibrium in this economy is defined as sequences of:

[14] This is referred to as "counter-cyclical capital buffer" meaning that the capital buffer demanded is intended to decrease fluctuations. See Basel Committee (2010).

[15] Angeloni and Faia (2013) use a similar function to model Basel III requirements.

- allocations $\{d_t, n_t, k_{t+1}, D_{t+1}, \pi_t^l, F_{t+1}^l, W_{t+1}^b, W_{t+1}^l, L_{t+1}, \theta_{t+1}, \pi_t^b, F_{t+1}^b, c_t,$ $s_{t+1}, T_t, \bar{\bar{\omega}}_t, y_t, k_{rr,t}\}$,
- prices $\{p_t, w_t, R_t, r_t^b, r_t^l, i_t, q_t\}$,
- shock processes for $\{\rho_t, \xi_t, z_t\}$ as given above,

such that, taking prices as given, agents maximize their future expected payoffs, the household and the firm's problem are consistent, the government budget is balanced at each period and markets clear. In particular, the following equations hold: $W_{t+1}^b = W_{t+1}^l$ and $s_t = 1$.

1.4. Calibration

This section discusses the calibration of parameters. We calibrate the parameters closely to de Walque et al. (2010), so as to match U.S. historical quarterly data from 1985Q1 to 2008Q2. The calibration of the banking sector is set to match main U.S. banking sector ratios. Notably, there are twice as many retail deposits in the economy than loans to firms, and twice as many loans to firms than inter-bank lending. In addition, securities in the banking sector are four times larger than the banking sector's buffer capital. Therefore, $D^l/L = 2$; $I/L = 0.5$; $B^b/L = 1$; $(F^b + F^l)/(B^b + B^l) = 0.25$.

Parameters in the banking sector, including regulatory weights, take the same value as in de Walque et al. (2010), with one exception. It is assumed that the lending bank is able to recover 90% of bad loans so that $\tau^l = 0.9$. It is set to 0.8 in the study of de Walque et al. (2010). Given the model and the calibration, a larger value of the default compensating rate τ^l insures that the shadow value of the profit constraint is large enough for the buffer capital accumulation constraint (1.2.19) to bind. Indeed, from (1.2.24) in the steady state, $\gamma^b = \left(\lambda^b - 1/\pi^b\right)/v_b$.

The real sector (households and firms) is calibrated as follows. The benefit of debt over equity is set to 35% so that $\tau = 0.35$, as in Jermann and Quadrini (2012). As mentioned earlier, the parameter χ is set close to zero, $\chi = 0.01$. Also, the depreciation rate of capital δ which is set to the standard value of 0.025.[16]

There is no consensus as to the value of capital adjustment costs. The

[16] de Walque et al. (2010) use 0.03.

estimated values range between 0 and 0.6.[17] Furthermore, Lintner (1956)'s model of dividend payout policy predicts that $\kappa = 0.3$. However, Brav et al. (2005) suggest that the value of this parameter is slightly lower due to the degree of freedom that share repurchases offer to firms. Lambrecht and Myers (2012) and Skinner (2008) suggest taking $\kappa = 0.55$.[18] Hence, the dividend adjustment cost parameter is set to $\kappa = 0.3$ and the capital adjustment cost parameter to $\phi = 0.1$, so as to match the relative volatility with output of firms' lending rate r_t^b after a 1% financial shock.

We now turn to the steady state values, defined by $x_t = x_{t+1} = x$. As in de Walque et al. (2010), labor in the steady state is $n = 0.2$, and the inter-bank lending repayment rate is 99% such that $\theta = 0.99$. The productivity, financial and liquidity variables, in the steady state, take the following values: $z = 1$; $\bar{\rho} = 0.3$; $\xi = 0.1634$. The liquidity variable is calibrated according to Jermann and Quadrini (2012) estimations. The persistence of the productivity and liquidity shocks also match estimations in Jermann and Quadrini (2012). The persistence of the financial shock implies that it takes one year for the return on financial assets B^i, $i = b, l$ to go back to its initial value. Therefore, the matrix defining the persistence of shocks is

$$A = \begin{bmatrix} 0.9457 & -0.0091 & 0 \\ 0.0321 & 0.9703 & 0 \\ 0 & 0 & 0.5 \end{bmatrix}.$$

The steady state level of the inter-bank interest rate i and the deposit rate r^l differ from their values calibrated in de Walque et al. (2010). This is explained by the introduction of the collateral constraint in the model. Indeed, by equation (1.2.9), the equality $\mu = (1/R - \beta)\left(1 + r^b\right)/\xi$ must hold. Thus, for the constraint to be binding at the steady state, the inequality $1/R > \beta$ is required, which implies that the borrowing cost, including the tax advantage, is lower than the return on savings ($R < 1 + r^l$). The values are therefore set to $r^l = 0.011$ and $i = 0.013$. It is, respectively, equal to 0.0035 and 0.007 in de Walque et al. (2010). The interest rate calibration implies that $\beta = 1/\left(1 + r^l\right) = 0.99$. It is set to 0.996 in de Walque et al. (2010).

[17] Bernanke et al. (1999) argue that capital adjustment costs convexity parameter is between 0 and 0.5. In their estimated DSGE model, Christensen and Dib (2008), estimate this parameter to be equal to 0.59.

[18] Jermann and Quadrini (2012) set $\kappa = 0.1460$.

Table 1.4.0.1. – Calibrated parameters

Banks				**Firm and household**	
$k_{rr} = 0.08$	$\overline{\omega} = 0.8$	$v_b = v_l = 0.5$	$\tau^l = 0.9$	$\overline{d}$=0.04	$\phi = 0.1$
$d_b = 4.41$	$\widetilde{w} = 1.2$	$\zeta_b = 0.07$	$B = 2.49$	τ=0.35	$\vartheta = 3.06$
$d_{F^b} = 1.37$	$\omega_b = 65.09$	$\zeta_l = 0.036$	$\bar{\rho} = 0.3$	$\delta = 0.025$	$\chi = 0.01$
$d_{F^l} = 3.65$	$\overline{\overline{\omega}}$=0.2	$\beta = 0.99$		$\kappa = 0.3$	$\bar{D} = 4.99$

Given these calibrations, the implied steady state values and some aggregate ratios are calculated. They are displayed in Appendix 1.10.A. In particular, notice that the lending bank has less buffer capital steady state level than the merchant bank's, $F^l_{ss} < F^b_{ss}$. This guaranties that the lending bank is a net lender on the inter-bank market and borrows from the households.[19]

From the parameter and steady state values, we infer values of the default cost ω_b, insurance parameters ζ_b and ζ_l, the market book value $B = B^b = B^l$, the deposit long run value $\bar{D}$, and utility parameters d_b, d_{F^b}, d_{F^l} and ϑ. Table 1.4.0.1 gives the list of calibrated and inferred parameter values.

Table 1.4.0.1 shows that the values of the parameters are relatively similar to the ones in de Walque et al. (2010). Only the implied values of the utility parameters both banks derive the buffer capital cushion d_{F^i}, $i = b, l$ are quite different. It is smaller in the model developed in this chapter than in de Walque et al. (2010). Indeed, the parameters are $d_{F^l} = 53.4$ and $d_{F^b} = 6.71$ in de Walque et al. (2010).

The minimum buffer capital parameter k_{rr} shows that buffer capital has to exceed at least 8% of the risk weighted assets, as required by Basel accords. Because, market books bear an extra market risk, the weight for market book $\widetilde{w}$ are assumed larger than the ones on loans $\overline{\omega}$. Depending on the asset category, these weights vary between 0 and 150%. Hence, their values are set to 80% and 120%, as in de Walque et al. (2010).

The calibration also implies that the merchant and the lending banks pay,

[19] Precisely, it implies, that the merchant bank derives less utility from the cushion of buffer capital above the minimum capital requirement which makes the merchant bank less risk averse. The merchant bank thus has a preference for consumption today relative to the lending bank. Preference for consumption today could eventually be modeled by assuming that the lending bank has a lower discount rate (or a higher discount factor) than the merchant bank. This assumption is often used in markets for borrowing and lending. See for example Brunnermeier and Sannikov (2014) or Iacoviello (2015).

respectively, 7% and 4.5% of their buffer capital to the insurance fund.

1.5. Transmission of financial shocks

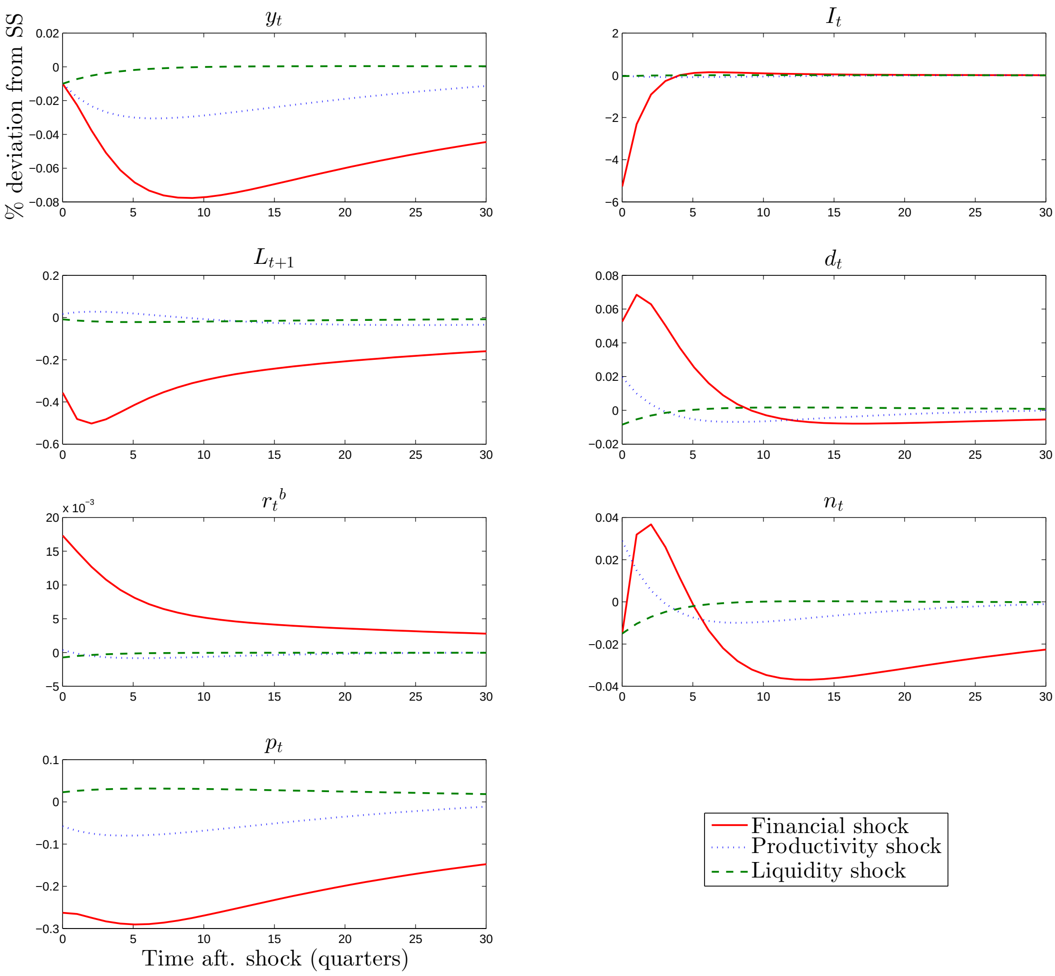
This section discusses and compares the transmission mechanism of shocks originating within the financial intermediation sector, financial shocks, with two other types of shocks: productivity shocks to firms' production and shocks to the collateral value of firms, liquidity shocks. It also shows the role of each financing friction in affecting the propagation of financial shocks.

Figure 1.5.0.1 displays the responses of some key macroeconomic variables to a negative liquidity, productivity and financial shock that reduces output by 1% on impact. It thus compares the role of shocks originating within the financial sector with real shocks and liquidity shocks. Simulated results of the model show that recessions induced by financial shocks are deeper and last longer than productivity and liquidity shocks. This result is consistent with Boissay et al. (2016), Claessens et al. (2012), and Caldara et al. (2013) who find that financial shocks last longer than typical business cycles. Following a financial shock, output y_t, continues to decrease for eight quarters after the initial disturbance. In contrast, output continues to fall during five quarters after a negative productivity shock and converges back to its long run value directly after the liquidity shock. The initial decrease in output is amplified eight times in the case of the financial shock. It is also amplified after a productivity shock, yet, by less than half the amount. In addition, while the persistence of investment is about the same in all three types of shocks, labor declines for ten quarters following a financial shock. This is in contrast to the other two types of shock. The transmission mechanism of each shock to the real economy are detailed hereafter.

A negative liquidity shock is an increase in the probability banks cannot recover their intra-temporal loans ξ_t in case firms decide to default. It thus corresponds to an exogenous rise in the enforcement constraint tightness (1.2.2), which reduces the inter-temporal loan demand L_{t+1}. Furthermore, (1.2.11) shows that the demand for labor n_t and net dividend payouts d_t fall. As a consequence, firms substitute debt for equity financing. Since firms' funds are not perfectly substitutable, investment expenditure I_t and production y_t are reduced.

A negative productivity shock is explained as follows. Recall productivity

Figure 1.5.0.1. – Shock comparison



Note: Both panels are simulated with a 1% shock to output. The variable y_t is output, I_t is investment, L_{t+1} is loans to firms, d_t is net dividend payments, r^b_{t+1} is the interest rate on loans to firms, n_t is labor. All variables are in % deviation from the steady state except for net dividend payments and the interest rate.

shocks occur before the intra-temporal loan is contracted. Thus, a negative productivity shock that exogenously decreases production leads to a fall of the intra-temporal loan, lowering the enforcement constraint tightness.[20] Consequently, from (1.2.11), there is an increase in labor demand, dividend payouts and the demand for inter-temporal loans. Furthermore, the negative productivity shock decreases the marginal product of capital which reduces investment. Nevertheless, this effect is mitigated by the relaxation of the collateral constraint.

As a consequence, the enforcement constraint leads firms to, after both liquidity and productivity shocks, substitute one type of financing by another. Therefore, firms financial structure allows firms to smooth the negative impact both shocks have on investment.

The transmission mechanism of an adverse financial shock that decreases profits of both banks is as follows. A fall in profits raises the shadow value of resources of both banks and, thus, by (1.2.14), raises inter-bank default. Moreover, from (1.2.12) and (1.2.19), the decrease in profits in period t decreases banks' buffer capital next period and hence, banks' buffer capital cushion. As a consequence, both banks decrease their lending. This corresponds to a leftward shift of the supply of loans on the loan market to firms and on the inter-bank market. Equilibrium is restored with an increase in the interest rate on these markets (r_t^b and i_t). The inter-bank interest rate increases, furthermore, with inter-bank default. Finally, the loss in banks' profits raises the shadow value of banks' accumulation of buffer capital. Therefore, the lending bank demand for deposits increases to enable it to build back its resources. Keeping the real sector unchanged, the right shift in the demand for deposits is followed by an increase in the interest rate on retail deposits r_t^l. On the market for household savings, an increase in the interest rate goes along with larger retail deposit supply D_{t+1} from households. This is noticed in (1.2.28) assuming consumption is constant.

In the model developed here, households can also invest in firms' stocks. Hence, the increase in the deposit rate leads to an increase in dividend payments from the firm. Indeed, rising rates on financial markets increases the required rate of return on equity shares. From (1.2.26) and (1.2.28), an increase in the deposit rate leads to a decrease in the inter-temporal marginal rate of

[20] The firm borrows less 'money' because, as output is reduced, it will be able to reimburse less.

substitution. Households and thus firms give less weight to tomorrow and invest less in shares.[21] As a consequence, firms' value p_t, inter-temporal debt and net equity issuance decrease, with large negative consequences on investment. Additionally, the rise in net dividend payouts increases the firm's enforcement constraint tightness, which raises the marginal cost of labor, reducing labor demand. Output is furthermore diminished. Consequently, due to the contagion of financial shocks to the equity market, both firms external financing diminish, amplifying the reduction in investment and output. In addition, output is furthermore reduced as rising costs tighten the collateral constraint and decreases labor demand.

Therefore, the model predicts that financial shocks are amplified by the financial contagion of the financial shock to the equity market, which leads firms' to reduce equity financing. Thus, the initial fall in external finance from the credit crunch initiated by a fall in banks' profits is amplified. The rise in net dividend issuance tightens the credit constraint, forcing firms to decrease their demand for labor, reducing further output.

To quantify the size of the amplifier generated by the model, I compare the standard deviation of output from a negative financial shock with the one in the model of de Walque et al. (2010). In the baseline specification and calibration, an initial decrease of 1% in the return on securities held by banks (financial shock) yields a standard deviation of output of 0.41. The standard deviation of output in the baseline model of de Walque et al. (2010) is 0.06.[22] This suggests that our model generates a financial accelerator that is 6.8 times higher than the one generated in de Walque et al. (2010).

Furthermore, the model adds features that are observed in the data. Indeed, the model with financial shocks developed in this chapter is able to reproduce the pro-cyclicality of asset prices and both firms' debt and equity issuance. This is in contrast to the Jermann and Quadrini (2012) study on financial shocks driven business cycles. The pro-cyclicality of both firms' debt and equity financing is empirically and theoretically corroborated (Covas and Den Hann, 2011; Covas and Den Haan, 2012; Levy and Hennessy, 2007; Korajczyk and Levy, 2003; Choe et al., 1993). The "financial shock" in Jermann and Quadrini

[21] The inter-temporal marginal rate of substitution equates, by consistency, to the stochastic discount factor of firms.

[22] Notice that labor is constant in the model of de Walque et al., 2010 and banks and firms can endogeneously default on their loans. When labor is not constant the standard deviation is 0.31.

(2012) is, however, different and corresponds to the liquidity shock. Due to the collateral constraint, banks are insured against shocks that happen in the production sector. A reduction in loan demand can be compensated for by an increase in equity issuance. In the model developed in this chapter, the combination of the credit crunch and the increased return on equity via contagion of the financial shock to the equity market leads to firms distributing more dividends. This result is consistent with empirical regularities found in Gilchrist and Zakrajsek (2012).

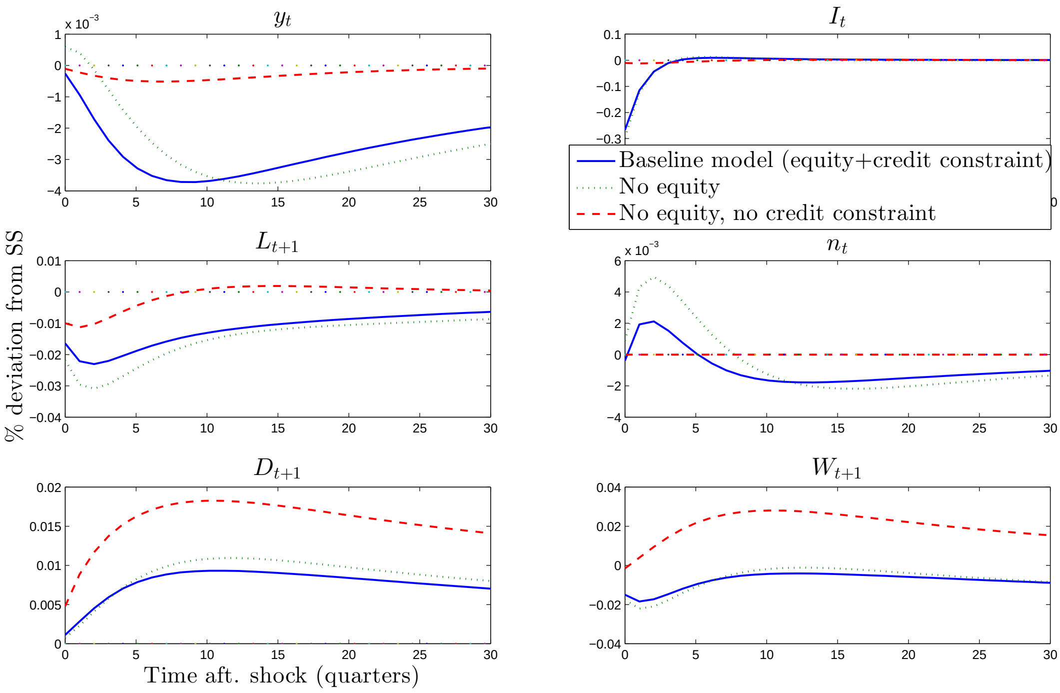
Financial shocks have also very persistent effects on the economy. While the shock process implies that the financial shock lasts only for one year, output moves away from its steady state for twice as long before converging slowly to its steady state level (see Figure 1.5.0.1). The empirical and theoretical studies of Boissay et al. (2016) and Caldara et al. (2013) also find that financial shocks have very strong and persistent effects on the economy. This is due to the feedback loop between the real and the financial sector. The initial credit crunch combined with the decrease in equity issuance triggered by the negative market book shock leads to depressed investment, lowering future output and the demand for credit. Duchin et al. (2010) also find, in an empirical study on the last subprime crisis in the U.S., that the persistent decrease in firms' external debt is rather a demand side effect as supply constraints weaken. Banks need to increase their profits to rebuild their buffer capital, but it takes time since credit demand is slowed by the credit constraint. As long as the financial sector experiences difficulties, the equity and the lending market are under stress, slowing the real sector's recovery. Therefore, the model is able to explain why crises originating within the financial sector last longer than other recessions. The interaction of financial shocks with firms' credit constraints are key to generating persistent macroeconomic effects.

Most macroeconomic models are criticized because they generate no persistence beyond the one that are already in the shocks. Considering serially uncorrelated shocks, Appendix 1.10.B shows that financial shocks, unlike productivity and liquidity shocks, have large persistent effects on output, eventhough they are themselves not persistent.

To summarize, collateral constraints are key in the amplification and persistence of shocks occurring within the financial sector, and when firms can imperfectly substitute bank credit for debt issuance.

Figure 1.5.0.2 shows the impact of the financing frictions on the transmission

Figure 1.5.0.2. – Firms financial structure contribution to financial shocks



Note: The models are simulated with a 1% negative financial shock. It is assumed with $\phi = 0$. The variable y_t is output, I_t is investment, L_{t+1} are loans to firms, $W_{t+1} = W^b_{t+1} = W^l_{t+1}$ are inter-bank loans, D_{t+1} are retail deposits, n_t is labor. Every variable are expressed in log deviation from the steady state.

mechanism of financial shocks to the real economy. It is assumed there are no adjustment costs ($\phi = 0$). It compares the impulse response functions of output y_t, investment I_t, loans to firms L_{t+1}, labor n_t, retail deposits D_{t+1}, inter-bank lending W_{t+1} following a 1% negative financial shock, with two alternative specifications. The first alternative corresponds to the baseline model in which firms do not issue equity. Hence, households are no longer shareholders of firms and invest only in deposits. This first comparison help to apprehend the role of financial contagion via the banking sector. The second alternative considers that firms do not issue equity and are not subject to an enforcement constraint. Instead, firms default on 5% of their loans and are subject to default costs, as in de Walque et al. (2010).[23] This last comparison allows to pin down the role of the enforcement constraint in the transmission of financial shocks.

Compared to the specification with only bank credit and the enforcement constraint, the baseline model produces a greater volatility of output. Quan-

[23]Labor is constant, as in de Walque et al. (2010).

titatively, an initial decrease of 1% in the return on securities held by banks (financial shock) yields a standard deviation of output of 0.35 in the model with debt financing only. It is 0.41 in the model with firms financial structure. Hence, compared to the model with only firms' bank debt, firms' financial structure choice amplify the volatility of output by 17%. Hence, financial contagion via the banking sector is responsible for 17% of output's volatility.

Moreover, the persistence of variables in both models are relatively similar. The differences in the initial response of output and labor demand is worth pointing out. Labor and output increase on impact in the model in which firms cannot issue equity, while the increase is much less pronounced in the baseline model. As financial shocks reduce the supply of loans, firms enforcement constraint loosens and therefore, firms increase their demand for labor. In the model with equity issuance, firms increase dividends, tightening their constraint. Labor is unaffected at the time of the shock.

In what follows I compare the baseline model with the model in which there are no enforcement constraint nor equity issuance, but firms' default. In the baseline model output y_t, loans to firms L_{t+1} and inter-bank lending W^l_{t+1} decrease persistently after a negative financial shock. Retail deposits D_{t+1}, in contrast, rise. Lower inter-bank activity and rising retail deposits have been documented to happen following the onset of the last financial crisis in Europe and the U.S. For instance, Meh and Moran (2010), Dib (2010), and Gerali et al. (2010) all find that inter-bank deposits fall after financial shocks. The long lasting fall in loans to firms, inter-bank loans and output contrasts with the results of the model that incorporates only firms' bank credit and exogenous default, as in de Walque et al. (2010). Hence, the collateral constraint is able to explain the persistent effect of financial shocks on key macro-economic variables as well as the counter-cyclicality of inter-bank lending.

1.6. Moments

This section presents selected moments generated by financial shocks in the model. To see how the model compares to the data and to similar studies, they are compared to ones that are generated by the study of de Walque et al. (2010). The results are displayed in Table 1.6.0.1.

The standard deviation of output is 0.06 in the model of de Walque et al. (2010) and is 0.42 in the model, which is closer to standard RBC models results.

Table 1.6.0.1. – Moments comparison

	relative std			corr. with output			first order autocorr		
variables	data	Mod^f	dW	data	Mod^f	dW	data	Mod^f	dW
r^b	1.2	1.2	6.88	0.36	-0.12	-0.55	0.9	0.65	0.77
i	1.2	1.33	5.83	0.49	-0.13	-0.43	0.88	0.66	0.75
r^l	1.2	1.31	5.66	0.47	-0.14	-0.46	0.88	0.66	0.75
γ	.01	0.06	0.29	0.11	0.39	-0.21	0.87	0.85	0.87
n	.99	1.04	0	0.88	0.09	1	0.88	0.74	0
y	1	1	1	1	1	1	0.86	0.95	0.95
L^b	4.03	8.60	30.54	0.36	0.47	0.24	0.79	0.83	0.80
D^l	1.38	2.23	28.41	-0.11	-0.99	-0.96	0.87	0.95	0.94
F	4.62	1.97	7.54	0.01	0.91	0.83	0.64	0.95	0.95
W^s	8.21	5.43	53.13	-0.24	0.10	-0.78	0.81	0.79	0.94
W^b	6.95	5.43	53.13	0.44	0.10	-0.78	0.87	0.79	0.94
π	47.3	11.5	37.84	0.13	0.41	0.57	0.78	0.7	0.68
c	0.82	1.56	7.89	0.81	0.02	0.31	0.83	0.62	0.66
I	4	71.7	32.00	0.89	-0.33	0.25	0.92	0.38	0.80
w	0.38	1.44	1	0.12	0.03	1	0.66	0.52	0.95

Note: Variables except for interest rates and default rates have been logged. They all have been hp filtered. Mod^f corresponds to our model, simulated with a 1% negative financial shock. dW correspond to the moments generated by the model of de Walque et al. (2010) with a 1% financial shock. The variable π stands for the sum of the profits of both banks. The variable F is the sum of each bank buffer capital. The other variables are as in the description of the model. Real data have been taken from de Walque et al. (2010) study except for labor and wages (King and Rebelo, 1999).

The model simulated with a 1% financial shock matches quite well the observed relative standard deviations of interest rates, labor, deposits, and inter-bank lending and borrowing. Compared to de Walque et al. (2010), the model fits better all relative standard deviations except for banks' profits and investment. The volatility of banks' profits generated by the model is lower than in the data. In addition, financial shocks produce a much larger standard deviation of investment than in the data. Financial shocks are amplified through financial contagion to the equity market, reducing both external financing and thus investment. The financial contagion leads firms to increase net dividend payouts, increasing the firm's enforcement constraint tightness and reducing firms' investment. This effect could be partly overcome by allowing heterogeneity in firms' degree of financial constraint. Nevertheless, the result of large volatility of investment is in line with theoretical and empirical studies on financially constrained firms (Campello et al., 2010; Duchin et al., 2010). It is found that investment decline in times of financial disturbance is bigger for financially constrained firms, particularly those firms relying the most on external finance such as credit and equity finance (Duchin et al., 2010).

Compared to de Walque et al. (2010), the match to the data of the correlation with output of interest rates, bank default, loans to firms, bank profits, inter-bank lending and wages is also improved. In particular, it is able to reproduce the pro-cyclicality of inter-bank repayment rate and inter-bank borrowing. However, similarly to de Walque et al. (2010), the model predicts counter-cyclical interest rates, as opposed to real data. Negative financial shocks reduce lending, raising, in equilibrium, the lending rates. Investment is also counter-factual: it is negatively correlated with output. This is partly explained by the collateral constraint. Indeed, while investment decreases after a negative financial shock, it goes back quickly to its long run value, unlike output which exhibits more persistence.

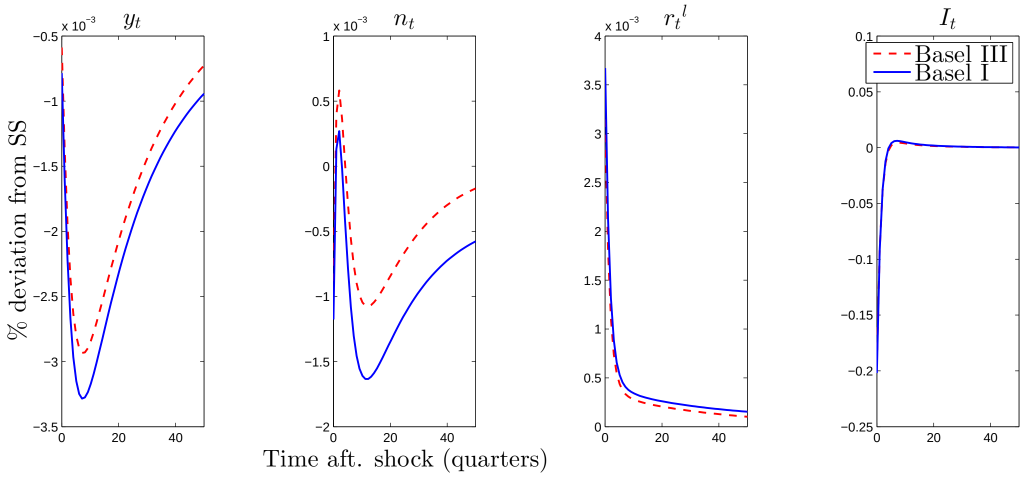
The first order auto-correlations simulated are comparable to the data. The first order auto-correlation generated by a financial shock are closer to real data than the ones generated with the model of de Walque et al. (2010) for wages, profits, loans to firms, labor, and output. The first order auto-correlations of deposits and loans are slightly lower than in de Walque et al. (2010) but still relatively close to observations. The persistence of interest rates, consumption and investment are lower than in the data and in de Walque et al. (2010).

1.7. Policy analysis: Basel III

de Walque et al. (2010) analyze the effect of introducing risk-sensitive capital requirements, as in Basel II, on subsequent business cycle fluctuations. The regulation thus follows (1.2.31). They find that capital requirements based on credit risk, as in Basel II, amplify the transmission of productivity and financial shocks. This section analyses the effect of counter-cyclical capital requirements, similar to those introduced in Basel III, where (1.2.32) is imposed.

It has been previously argued that pro-cyclical policy requirements, as in Basel II, enhance output fluctuations during crises and that counter-cyclical requirements, as introduced in Basel III, reduce fluctuations. Figure 1.7.0.1 shows the impulse response functions of output, y_t, labor, n_t, the interest rate on retail deposits, r_t^l, and investment, I_t, following a 1% negative financial shock, with constant risk weighting (Basel I) and counter-cyclical weights

Figure 1.7.0.1. – Financial shocks, counter-cyclical buffer effect



Note: Impulse response functions to a 1% negative financial shock. The variable y_t is output, n_t is employment, r_t^l is the deposit rate, I_t is investment. All variables are in % deviation from the steady state except for the interest rate.

(Basel III). As expected, compared to fixed capital requirement ratios, counter-cyclical capital requirements introduced in Basel III reduce the negative impact financial disturbances have on output and labor. They reduce minimum capital requirements of banks in bad times. Hence, banks' demand for deposits is relatively larger. The interest rate on deposits is lower. By non-arbitrage, dividend issuance is also lower, thereby, reducing dividend adjustment costs. Lower adjustment costs allow firms to dampen their reduction in labor demand and thus production.

1.8. Discussion

This section analyses the sensitivity of the results to three modeling assumptions. The first part discusses the modeling of the dividend adjustment costs function, but then uses an alternative that is more in line with the literature on firms' dividend payouts. The second investigates the role of capital adjustment costs on the outcome of the model. Finally, the problem of the two banks is slightly modified to allow banks to choose how much to consume in each period, and to suppress the banks' insurance scheme.

1.8.1. Dividend adjustment costs

Lintner (1956)'s study shows that dividend payout policy is a function of the firm's current profits, p_t, scaled by a long term target payout ratio. He also shows that firms smooth out dividend payouts from one year to the next. Also, the change in dividend payouts between two time periods is a linear function of the difference between the long term dividend target level (itself a function of current profits, p_t) and the dividend payouts d_{t-1} in the last period, and earning shocks. The following way of modeling dividend adjustment costs is thus more in line with observations made by Lintner (1956) and later confirmed by recent empirical and survey evidence:[24]

$$\psi\left(d_t\right) = d_t + \kappa\left[\frac{(1-\beta)}{\beta}p_t - d_{t-1}\right]^2,$$

where the fraction that multiplies p_t allows the dividend cost to be equal to zero in the steady state. A recent study on Linter's model application in recent times (Lambrecht and Myers, 2012) uses the same function to empirically evaluate firms' dividend payout rules.

The first order with respect to d_t becomes $\lambda_t = 1+2\kappa m_{t+1}\lambda_{t+1}\left[(1-\beta)\,p_{t+1}/\beta - d_t\right]$. This dividend payout function yields similar results to the one used in the baseline model, for values of κ within the range suggested by empirical studies.[25]

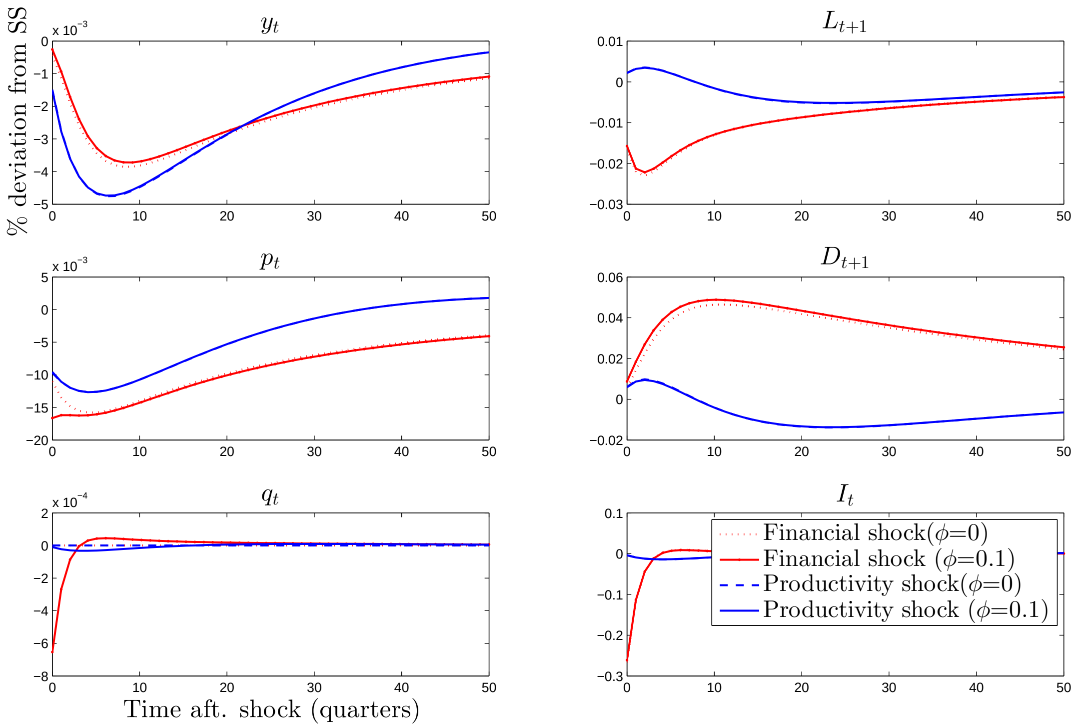
1.8.2. Capital adjustment costs

Capital adjustment costs are introduced in the model in an attempt to bring the model closer to reality and to analyze their consequences when a financial shock occurs. In particular, it allows the price of capital to fluctuate and is thus a channel through which exogenous shocks are transmitted. To understand the role of capital adjustment costs in the propagation of shocks, the consequences of the introduction of such costs is discussed for the financial shock and the productivity shock. Figure 1.8.2.1 displays the response of output y_t, loans L_{t+1}, stock price p_t, deposits D_{t+1}, the price of capital q_t, and investment I_t to negative financial and productivity shocks, with and without capital adjustment costs. Adjustment costs associated with varying capital dampen the impact both shocks have on the economy. The effect is larger for financial shocks than

[24] Michaely and Roberts (2012), Brav et al. (2005).

[25] Empirical studies suggest this value is between 0.1 and 0.6.

Figure 1.8.2.1. – The effect of capital adjustment costs



Note: Impulse response functions to a 1% negative financial shock. The variable y_t is output, L_{t+1} are loans to firms, p_t is firm's stock price, D_{t+1} is retail deposits, I_t is investment, q_t is the price of capital. All variables are in % deviation from the steady state except for net dividend payments.

for productivity shocks. The intuition is as follows.

As discussed above, negative financial shocks lead firms to distribute more dividends which raises the degree of the borrowing constraint tightness. Capital adjustment costs raise the enforcement constraint tightness, dampening the initial increase in dividend issuance. With capital adjustment costs, households buy relatively less stock, reducing stock prices further, and deposit more with the lending bank. Therefore, adjustment costs enable the financial sector to recover relatively more quickly, dampening the credit crunch and therefore the negative impact on output. Productivity shocks do not impact the financial sector itself. The enforcement constraint hedges banks against the productivity shock. Consequently, the dampening effect capital adjustment cost have on the financial sector (via an increase in deposit funds) is not present.

1.8.3. Endogenous bank consumption

In this subsection, I let banks endogenously choose their level of consumption c_t^b instead of fixing consumption as a constant fraction v_i, $i = b, l$ of profits. Moreover, the assumption that banks place a portion of their buffer capital into an insurance fund ($\zeta_b > 0, \zeta_l > 0$) may be subject to discussion. Indeed, expenses are deducted from profits rather than from their buffer capital. This feature is needed in the baseline model in order to have stationary series of buffer capital. This is no longer needed once bank consumption is endogenous. I thus assume $\zeta_b = \zeta_l = 0$.

Nevertheless, banks buffer capital are often considered to be sticky.[26] It has been shown that there are costs to varying bank capital as it allows banks greater risk tolerance. For example, Adrian and Shin (2010) show that banks target a fixed leverage ratio. It is therefore assumed to have quadratic adjustment cost in varying buffer capital: $\phi^F \left(F_{t+1}^i - F_{ss}^i\right)^2$, $i = b, l$. It can be interpreted as a pecuniary cost in varying banks' buffer capital because of some fees or regulatory requirements. This assumption allows to find the steady state value of banks' buffer capital. Finally, there are quadratic adjustment cost in varying profits: $\phi^\pi \left(\pi_t^i - \pi_{ss}^i\right)^2$, i=b,l. It can be interpreted as a pecuniary cost in varying profits. For example, fluctuating profits are badly regarded on financial markets so that the bank has a worse credit rating if profits vary too much, leading to some exogenous costs. This last assumption helps to determine the steady state values of profits.

The merchant bank problem can be rewritten as (the lending bank problem is symmetric except for default):

$$
\begin{aligned}
Max_{\left\{W_{t+1}, L_{t+1}, \theta_{t+1}, \pi_t^b, F_{t+1}^b, c_t^b\right\}} \sum_{t=0}^{\infty} & E_t \beta^t \{ln\left(c_t^b\right) - d_b(1-\theta_{t+1}) \\
& + d_{F^b}\left[F_{t+1}^b - k_{rr}\left(\overline{\omega} L_{t+1} + \widetilde{w} B^b\right)\right]\},
\end{aligned}
$$

subject to

[26] Gambacorta and Mistrulli (2004) conduct an empirical study on Italian banks during 1992-2001 and suspect that bank capital is sticky. They also suggest that adjustment costs in raising capital are higher for less capitalized banks (in this model it would imply that the adjustment costs are higher for the lending bank).

$$F^b_{t+1} = F^b_t + \pi^b_t - c^b_t - \phi^F \left(F^b_{t+1} - F^b_{ss}\right)^2,$$

$$\pi^b_t = L_t + \frac{W_{t+1}}{1+i_t} - \theta_{t+1} W_t - \frac{L_{t+1}}{1+r^b_t} - \frac{\omega_b}{2}\left[(1-\theta_t) W_{t-1}\right]^2 + \rho_t B^b - \phi^\pi \left(\pi^b_t - \pi^b_{ss}\right)^2.$$

The main results do not change compared to the baseline model. The consequences of a 1% negative market book shock on the firm's financing decision and on the real economy are similar with some rare differences. First, buffer capital decrease is much less pronounced in the endogenous banking consumption model. It is mostly due to the fact that it includes adjustment costs in the variation of buffer capital. Second, for the same reasons, profits are less affected by financial shocks. Since banks can now adjust their consumption, after negative financial shocks, banks consumption decreases and thus the budget constraint of banks does not tighten as much. As a consequence, the decrease in lending is less than in the baseline model and the interest rate increase is lower. More generally, the responses of real variables to a financial shock are less volatile. Finally, the decrease in buffer capital generated by the negative shock is more persistent in this second scenario, due to buffer capital and profit adjustment costs.

1.9. Conclusion

This study develops a coherent framework in which the consequences of financial shocks on firms' external financing decisions, and the consequences for the real economy, can be studied. It shows how financial intermediaries and firms' financial structure can help propagate and amplify financial shocks. Negative financial shocks raise bank demand for retail deposits, decrease inter-bank lending, and raise real interest rates. The combination of the credit crunch and the large costs of equity issuance have negative consequences on firms' external financing, greatly reducing investment, labor demand, and output. The study also emphasizes, from a theoretical point of view, the role of credit constraints in magnifying financial disturbances to the real sector.[27] The constraint leads the

[27] Campello et al. (2010) and Chava and Purnanandam (2011) show the same from an empirical ground.

credit supply crunch into a credit demand crunch, preventing a faster recovery of the financial sector and thus the real sector.[28] It is also able to explain the cyclicality of labor. The results suggest that, when a crisis originates in the financial sector, policies should aim at increasing firms' capacity to borrow, such as tax cuts on external financing. This should highly mitigate the negative effects of a financial crisis.

There are several extensions to this study that constitute future projects. The most straightforward extension is to introduce firm heterogeneity. Only some firms could then be financially constrained. It is expected to produce more realistic business cycle moments. We could allow the model to exhibit possible non-linearities in responses, and use an enforcement constraint that is more in line with the literature. This can be done by simulating the model with occasionally binding constraints. Finally, endogeneizing the market book to allow banks to choose between two different assets would also be an interesting extension.

[28] This mechanism is different from that of Bernanke et al. (1999) who emphasize the role of asset prices in depreciating borrowers' balance sheet.

1.10. Appendix

1.10.A. Comparison

Table 1.10.A.1. – Comparison of steady states

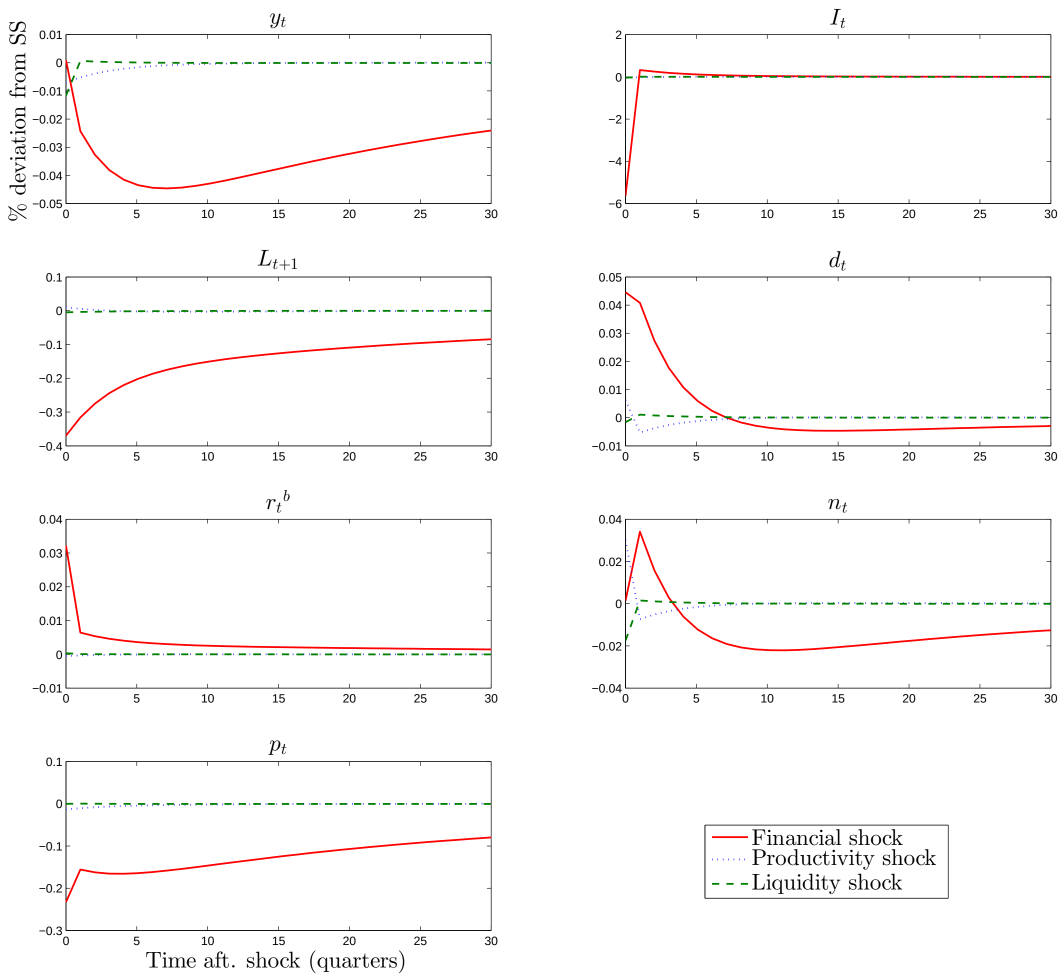
variable	Model	de Walque et al. (2010)	variable	Model	de Walque et al. (2010)
c	0.54	0.42	ρ	0.03	0.03
D	4.99	0.386	γ^b	16.93	107.01
L	1.997	0.193	λ^b	18.71	199.07
w	2.04	2.12	λ^l	67.62	592.7
n	0.195	0.2	γ^l	77.95	778.59
r^l	0.011	0.004	F^l	0.48	0.04
r^b	0.016	0.016	F^b	0.69	0.06
k	5.62	6.33	T	-0.07	0.01
y	0.60	0.63	q	1	
z	1	1	I	0.14	
λ	0.993	0.998	p	3.64	
π^b	0.098	0.0069	R	1.01	
π^l	0.035	0.096	s	1	
W	1.21	0.096	d	0.04	
i	0.013	0.007	ξ	0.1634	
θ	0.99	0.99	μ	0.0044	

Table 1.10.A.3. – Implied steady state ratios

	Baseline model	**de Walque et al. (2010)**
k/y	10	10
d/y	6.6%	4%
c/y	86.7%	66%
$\omega_b/2\,[(1-\theta_t)\,W_{t-1}]^2/\left(F^b+F^l\right)$	0.4%	0.3%
$\left(\pi^b+\pi^l\right)/\left(F^b+F^l\right)$	11.4%	12%

1.10.B. Shock comparison

Figure 1.10.B.1. – Shock comparison, with serially uncorrelated shocks



2. Empirical Investigation of the Effect of Bank Wholesale Debt on Loans and Output in the Euro-zone

2.1. Introduction

The last decades' developments in the banking sector (shadow banking, securitization, increased wholesale funding) have increased the interconnectedness in the financial sector, raising systemic risk (Rajan, 2005), and increased the responsiveness of banks to shocks (Disyatat, 2011).[1] According to policy makers and researchers (Gertler et al., 2016; Hanson et al., 2011; Tarullo, 2013), recent events have been triggered by disruptions in the wholesale banking sector. Wholesale fundings are items of banks' liability and account for nearly half of total liabilities in the Euro-zone. They include inter-bank deposits, short term securities (Money Market Fund shares) and bank debt issuance. Wholesale fundings contrasts with retail deposits because they have factually shorter maturities and are easier to raise than deposits (Diamond et al., 2001). Hence, wholesale fundings are largely conditioned by the macroeconomic climate, raising uncertainty.

Increased reliance of the banking sector on wholesale funding raises funding liquidity risk in case of a macroeconomic shock. Funding liquidity risk is the risk that banks investors do not roll over their funding as they would in normal times, and withdraw large amounts of funding during periods of stress. This can trigger fire sales and thus erode bank capital, possibly leading banks to

[1] Systemic risk is the risk that the whole financial system fails, as opposed to the risk of failure of a single entity.

default (solvency risk), increasing systemic risk. Since capital erosion limits banks ability to borrow, the reduction in banks' funding is amplified. Moreover, it increases the risk that banks are not able to meet their short term financial demand (liquidity risk). Falling funds reduce the size of banks, possibly leading to a cut in credit.

In this context, the literature has gained interest on the role of wholesale funding of banks in generating and propagating crises (Adrian and Shin, 2010; López-Espinosa et al., 2012). Most studies concentrate on the role of the most unstable wholesale funding, bank short term wholesale funding and inter-bank funding, in affecting economic activity. The role of bank long term debt issuance in the amplification and the propagation of the last financial crisis has not been assessed yet. Their share in total liabilities in the Euro-zone is about 14%. Although they are less volatile than other wholesale funds, they are nearly twice as more volatile than deposits and by raising uncertainty and leverage, can be a source of great instability (Brunnermeier and Sannikov, 2014).

The objective of this study is to evaluate the role of bank long term debt issuance in affecting loan supply and output in the Euro-zone from 1999Q1 to 2014Q4.

I present two contributions, one theoretical and one empirical. The theoretical model of Bernanke and Blinder (1988) is extended in Section 2.4 by incorporating a market for bank wholesale debt funding. I then follow Driscoll (2004)'s empirical strategy by using a two stage least square instrumental variable linear regression to identify shifts in the loan supply equation (Section 2.6). Driscoll (2004) uses shocks to deposits to instrument for loan supply. His framework is extended by adding a second instrument which represents changes in bank preferences for wholesale long term debt issuance. In addition to testing causalities between financial shocks, loan supply and output, I test the validity of the functional form of the model, in Section 2.7, using non-parametric instrumental variables (NPIV). Despite the theoretical evidence (Brunnermeier and Sannikov, 2014), the study of potential non-linearities of loan supply on output remains unexplored. This is of particular concern for policy and regulation in the banking sector. Indeed, a better understanding of the effect of loan supply on output may help policy makers. Non-parametric techniques are useful because they allow to reasonably fit the data without making any assumptions on the parametric family of the data. They are used as an explanatory tool and may help confirm an expected parametric form. To test the validity of the model I embed the linear empirical specification into a more general class of model called General Additive Models (GAM) (Hastie and Tibshirani, 1990), fitted with local linear kernel regressions.

Additionally, increasing the number of instruments allows precision of the estimates to be increased, an improvement in the two stage least square (2SLS) estimator efficiency, and the construction of a test for endogeneity of the instruments (test for over-identifying restrictions). Moreover, the ability to recover non-linearities in NPIV is positively linked to the strength of the instrument (Newey, 2013).

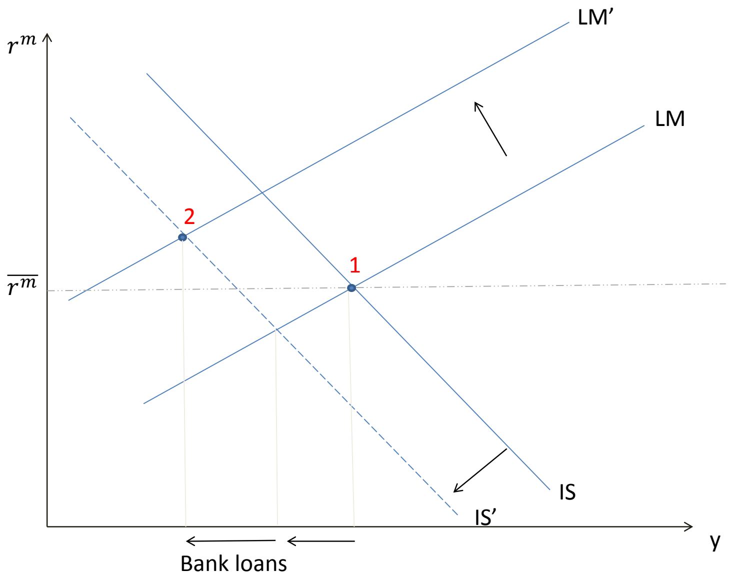
The next Section 2.2 exposes published works on bank liability structure and its effect on economic activity. Section 2.3 describes the data. Section 2.5 presents the estimation of financial shocks, Sections 2.6 and 2.7 give the linear and non-parametric 2SLS results. Section 2.8 concludes.

2.2. Literature

I first review the theoretical papers on the role of financial structure in affecting loan supply and output. I show how potential non-linearities can arise. Then, the empirical evidence on the effect of bank wholesale funds on loan supply and loan supply on output is presented.

Bernanke and Blinder (1988) develop the benchmark theoretical model of the role of financial structure on economic activity. The authors extend the standard Keynesian IS-LM model by incorporating a market for banks' loans. The IS-LM model is a stylized framework in which short term economic transmission mechanisms of shocks can be analyzed. There are three types of agents: a government, a central bank, and a set of non bank agents (households and firms). There are two financial assets, bonds and money, and consumption and investment goods. Figure 2.2.0.1 shows the two curves that represent all the equilibrium points on the goods market, the IS curve, and all the equilibrium points on the money market, the LM curve. By clearing the goods and the money markets, the bonds market automatically clears by Walras' law. The IS curve displays a negative relationship between output (y) and the interest rate on the financial asset (r^m) while LM shows that the interest rate is a negative function of output. Point 1 on the graph is the only point in which all markets

Figure 2.2.0.1. – IS-LM-Bank Loans



are in equilibrium.

Bernanke and Blinder (1988) introduce a third financial asset, loans that are supplied by commercial banks. They also assume that bonds and loans are imperfect substitutes due to asymmetric information or liquidity differences. Therefore, investment is also affected by the lending rate. They thus define a modified IS curve in which loans and bonds are imperfect substitutes, and given that, the loan market also clears.

In the model, exogenous shocks to money affect the economy as follows. By reducing the quantity of money in the economy (LM shifts to LM'), interest rates rise, investment and output fall. Moreover, monetary policy decreases bank reserves and thus bank loans. In the standard Keynesian framework, since loans and bonds are perfectly substitutable, the reduction in bank loans is completely offset by a rise in bonds. Hence, the story ends here. When firms' funds are imperfectly substitutable, for a given interest rate, a decrease in loan supply lowers investment. The IS curve shifts to the left (IS') and output is further reduced. The new equilibrium point is point 2 in Figure 2.2.0.1. This is the so-called bank lending channel. It is the channel through which monetary policy affects economic activity via credit. It should be distinguished from the standard "interest rate channel", where changes in the nominal interest rate affect output. The authors also empirically analyze the contribution of credit and money demand shocks in affecting economic activity, but they do not evaluate shocks arising within the financial sector.

The theory behind the lending channel is found notably in Froot and Stein (1998) and Stein (1998). Froot and Stein (1998) present a theoretical analysis showing that banks actively manage their balance sheet to hedge against risk. Due to the inherent characteristic of a bank where the maturity of much of its debt is short, as opposed to the long term maturity of its assets, banks may face non hedgeable liquidity risks. Because some of the risk in the banking sector is not hedgeable, banks are also concerned about liquidity and leverage (in addition to profits) and thus hold non trivial amounts of capital (buffers). Therefore, banks have a hedging strategy in addition to deciding the quantity of debt they hold. In other words, the funding structure of the banking sector, such as capital leverage and the quantity of liquid funds in total funds, matters for the quantity of lending made. Stein (1998) offers some micro foundations for the importance of bank liability structure. The author shows that adverse selection problems between financial intermediaries and their investors give theoretical grounds to adjustment costs in varying uninsured funds. Hence, this points to the imperfect substitutability of banks' balance sheet items.[2] It is assumed that investors are not perfectly informed about how the bank manages its assets. There are thus some adjustment costs to be incurred when raising new uninsured funds. There are no costs for insured funds as they assume that they are the only way for banks to raise *asymmetric-information proof* external finance.[3] The further a bank attempts to substitute deposits for uninsured funds, the higher are the potential adverse selection problems.

Recent macroeconomic models have included an explicit bank financial structure. In particular, they have recently demonstrated heightened interest in the role of banks' wholesale funding in affecting macroeconomic stability. Gertler et al. (2016) extend the macroeconomic model of Gertler and Kiyotaki (2011) to include bank wholesale funding in addition to retail deposits. In their model, there are possible runs on wholesale inter-bank funding, such that creditors do not roll over inter-bank deposits. They argue that these specifics

[2] Examples of uninsured funds are wholesale CDs, subordinated debt, preferred stock, etc.

[3] Cornett et al. (2011) in fact shows that "deposits insulate banks from liquidity risk due to the advent of government guarantees". They are, as a consequence, less elastic sources of funding.

allow to better capture the development of the recent financial crisis. Disyatat (2011) develops a model in which capital is distinguished from other banks' funds. This work reformulates the bank lending channel to take into account recent developments in banks' market funding. In contrast with quantitative effects of the bank lending channel, the author focuses on the role of endogenous external finance premia and risk perception of banks regarding the impact on loan supply.

Brunnermeier and Sannikov (2014) develop a macroeconomic model in which the illiquidity of capital raises uncertainty and can give rise to potential non-linear effects of funding shocks on output by raising systemic risk. In their theoretical setup, market illiquidity of capital (defined as the difference between the first best price of capital minus the price to which prices may theoretically drop) determines endogenous risk. The greater is market illiquidity, the greater is the systemic risk because it raises market uncertainty. Consequently, the authors suggest that shocks to bank funding can affect non-linearly output in the sense that times of crisis are distinguished from normal times, by the uncertainty.

This study is also related to the empirical literature on the role of bank funding structure on bank lending, and to the literature evaluating the impact of lending on economic activity.

Studying the effect of loan supply on output goes through two main difficulties. The first is to identify a variation in loan supply. The difficulty of the task lies mainly in that demand from supply effects can hardly be distinguished, because credit supply and credit demand share common determinants (output, interest rates). The second difficulty is to identify the effect on output. A decrease in loan supply may well respond to a decrease in future expected output, and output may fall due to a cut in loan supply. The difficulty of the question has led to a large number of works testing if changes in loan supply affect output growth. In what follows, I briefly review the most relevant of them with respect to my study.

Based on Bernanke and Blinder (1988) model, Driscoll (2004) empirically tests the existence of the bank lending channel in the U.S. between 1969 and 1998. The author exploits the panel dimension and the common currency dimension of the U.S. to identify loan supply. He uses state specific shocks to money demand to instrument loan supply in a linear two stage least square estimation procedure. By viewing the U.S. states as small open economies with fixed exchange rates, any shock to money demand in one state is automatically accommodated so that output is left unchanged.[4] Nevertheless, the money demand shocks change bank deposits, loan supply and thereby, may affect output. Driscoll (2004) finds that, in the U.S., between 1969 and 1998 (annual data), shocks to bank deposits affect bank lending. However, he finds no evidence of a bank lending channel in the U.S. as loan variation is not found to affect output.

Driscoll (2004) argues that it is possible to identify the effect of a change in loan supply using shocks to deposits in the U.S. over the period studied (1969-1998) as inter-state lending and deposits were legally made possible from 1996. Still, state by state agreements on deposits and lending were made starting in the early 80s and opened inter-state markets. To identify the bank lending channel in a specific state, deposit and lending markets must be segmented across states.

Cappiello et al. (2010) and Rondorf (2012) reproduce Driscoll (2004) methodology in ten Euro-zone countries. The Euro-zone banking market remains segmented across countries.[5] Cappiello et al. (2010) follow closely the estimation procedure of Driscoll (2004) but include in the estimation of the effect of money demand shocks on loans a variable representing the tightness of bank credit standards.

In contrast with Driscoll (2004) who takes first differences of the data, Rondorf (2012) estimates money demand with an error correction framework. As real money balances and its determinants in the Euro-zone are non-stationary and follow the same long run trend, money demand must be estimated with an error correction framework, in which both the long run and short run variations are taken into account.

Both Rondorf (2012) and Cappiello et al. (2010) find evidence of a bank lending channel in the Euro-zone from 1999 to 2008, suggesting that firms and banks' funds are imperfectly substitutable during this period. Cappiello et al. (2010) find, in addition, that not only have volumes of credit affected output, but also bank credit standards.

[4]Real balances increase in that state and decrease in all other states

[5]The share of domestic deposits and domestic loans in total deposits and loans in all of the 10 Euro-zone countries is above 90% except for Belgium, Ireland (varies between 75 and 95%) and Austria and Finland in the years following the crisis (it falls to about 87%).

In contrast with panel techniques, Gambetti and Musso (2012) and Hristov et al. (2012) both use a VAR model to identify loan supply shocks and study their role on economic activity in the Euro Area. The first study spans from 1980 to 2011 and the second from 2003 to the second quarter of 2010. Both find evidence that loan supply has affected output. The VAR techniques abstract from a solid theoretical background. They measure exogenous variations in the supply of loans but do not identify the source of it. This is particularly cumbersome if one intends to understand the underlying economic mechanism.

All these studies assume that the relationship between loan supply and output is linear. There are few empirical studies that relate evidence on non-linearities. Schleer and Semmler (2015) consider non-linearities between the banking sector financial conditions and real economic activity. Based on a VAR regime switching model, they find that financial sector shocks led to large non-linearities and amplification effects in some Euro-zone countries, in particular after the collapse of Lehman Brothers. Bouvatier et al. (2014) use smooth transition regime regression models in 17 OECD countries and show that credit is non-linearly related to output variation. It is highly related to business cycles in times of high volatility. To my knowledge, there are no studies that investigate potential non-linearities that do not impose a functional form on the data.

Changes in loan supply can be due to monetary policy changes, bank funding shocks, or changes in market conditions such as increased risk perception. Most of the literature focuses on the role of capital and reservable liabilities in affecting loan supply. Recently, the literature has gained interest over the role of non-reservable liabilities of banks in affecting loan supply. Deposits, although theoretically liquid, are stable because they are insured. Wholesale funds contrast with retail deposits because they have factually shorter maturities and are easier to raise than deposits (Diamond et al., 2001). As a consequence, wholesale debt funding is part of banks' investment strategy and may have a sizeable impact on bank lending.

Gambacorta and Marques-Ibanez (2011) point out that the standard framework of Bernanke and Blinder (1988) is not able to take into account recent developments in the banking sector, as the role of deposits in bank funding has decreased (non-reservable liabilities have been increasingly easy to raise). The authors conduct an empirical investigation of the determinants of the loan supply schedule. They consider the effect of monetary policy on the bank lending channel in 1000 banks among 14 European countries and the US, from the first quarter of 1999 to the third quarter of 2009. They include a dummy variable (from the third quarter of 2007 to the fourth quarter of 2009) to their linear empirical specification to account for non-linear effects during the recent financial crisis. They find that banks' funding structure matters for lending in that increased short term funding and/or additional funding via securitization amplifies the cuts in bank lending during financial instability. Their result suggests a non-linear effect on the monetary transmission mechanism (bank lending channel), where crisis times and normal times are distinguished.

Cornett et al. (2011) study the role of bank liquidity structure in affecting credit supply in the U.S. during the years 2006-2009. They use a panel of banks on quarterly data. Their empirical model takes into account the fact that banks hold cash and liquid assets in their hedging strategy (to manage liquidity risk). They use four measures of liquidity risk management for banks and interact each variable with the TED spread.[6] The TED spread is a measure of market liquidity conditions and is believed to have surprised banks during the crisis, so that banks had to change their liquidity management policies. The spread thus allows them to separate effects of the crisis period from normal times. They find that banks with higher levels of liquidity risk exposure reduced lending more than others in periods of high TED spreads. They did this by building up liquidity buffers, for instance. It suggests that non-linearities in the loan supply, arising by a change in banks' funding structure, become larger with bank liquidity risk. The authors also find that banks with more stable sources of funding (such as deposits and equity capital) reduced lending less than other banks during the last financial crisis, and that banks with less liquid assets reduced loans to increase their liquid assets. Finally, the authors note that bank illiquidity had peaked after the fall of Lehman Brothers (last quarter of 2008).

Therefore, the two previously cited studies suggest that unstable and short term funding of banks affect non-linearly credit, in the sense that normal times and crisis times have a different impact.

This study is also related to the literature on bank debt issuance. Rixtel et al. (2015) investigate the determinants of bank wholesale long term debt

[6] The TED spread is defined as the difference between inter-bank rate minus the short term government T-Bill.

funding in 14 European countries.[7] Their empirical specification is additive and in log levels. The authors follow the banking literature, and the literature on debt issuance choice of firms, to theoretically motivate a set of long term bank debt issuance determinants. They use bank level data from 1999Q1 to 2013Q1 on 63 European banks as well as country level aggregated data. They show that country specific risks were detrimental to bank bond issuance in the euro-area. Notably, they find that financial market tensions affected more strongly bond issuance during the Great Recession.

This chapter extends the Bernanke and Blinder (1988) model by allowing banks to be funded via wholesale long term debt in addition to deposits. I construct an equation for the supply and the demand of bank long term debt. Based on the theoretical model, and using an error correction framework, I estimate shocks to the supply of bank debt, in addition to money demand shocks as in Driscoll (2004) and Rondorf (2012). I investigate, using both a linear and a non-parametric instrumental variable approach, the role of both financial shocks in affecting loans and output. The macroeconomic impact of disruptions in bank long term debt has not been assessed in the literature yet. Non-parametric techniques do not impose any functional form and help verify the validity of the linearity assumption of the model. Few studies have pointed out the existence of non-linearities between funding shocks and loan supply as well as between credit and output.

2.3. Data

This section describes and briefly comments the data used in the study. I use quarterly data, from the first quarter of 1999 to the last quarter of 2014. The countries studied are the eleven founder members of the euro except for Luxembourg.[8] There is thus Austria (AT), Belgium (BE), Finland (FI), France (FR), Germany (DE), Ireland (IE), Italy (IT), Netherlands (NL), Portugal (PT), and Spain (ES).

Country level output is measured by chained linked volumes of the Gross

[7] Austria, Belgium, Germany, Spain, France, Greece, Ireland, Italy, Luxembourg, the Netherlands and Portugal and non Euro-zone countries: Switzerland, Sweden and the United Kingdom.

[8] The share of the financial sector in total GDP in Luxembourg is much larger than in the other countries considered, rendering it an outlier.

domestic Product (GDP) series, published in Eurostat, as in Rondorf (2012).[9] The money supply is all the money in circulation (M3) minus currency and traveler's checks, as measured by countries' respective central banks. The monetary aggregate M3 includes bank deposits from the non-financial sector, with maturity less than two years (76% of total deposits), short term wholesale funds (Money Market Funds), and debt securities with maturity of up to two years. The measure of bank wholesale funding in this study corresponds to all domestic bank debt issuance with maturity of more than two years. All the bank balance sheet series are from the European Central Bank (ECB) website. The series are monthly outstanding amounts at the end of the period to non monetary and financial institutions (domestic loans can be found in the section domestic and cross border position of Euro area monetary financial institutions, by country).[10] Then, the outstanding amount of the last month of each quarter is taken. The long term interest rate is the quarterly average of monthly interest rates on the yield of a ten year government bond. It is available on the European Central Bank website, in the financial data section.

Credit to GDP gap and exports are also used in the study, as instruments for output in the estimation of money demand and bank debt issuance. The credit to GDP gap variable is taken from the risk dashboard data of the ECB. Exports are from Datastream. The deflator is the ratio of nominal GDP over the chained linked volumes (2010) of GDP from Eurostat. Population series are also from Eurostat.

All the series in the estimations are seasonally adjusted using the x-12-ARIMA seasonal adjustment of the U.S. Census Bureau, deflated and per capita except for interest rates.

I now analyze relevant balance sheet items and GDP series. The liability items of the banking sector can be broadly decomposed into retail funds, called deposits from non monetary and financial institutions (MFI), which are for most insured liabilities, wholesale funds, and bank own funds. Table 2.3.0.1 exposes the general evolution of the Euro-zone financial structure and economic activity, from 1999 to 2014. It displays some summary statistics on wholesale, deposits, loans and GDP average growth rates in the Euro-zone. The coefficient of variation (CV) reveals that wholesale funds are nearly twice as volatile as

[9]Quarterly population for Ireland is taken from the OECD website as it is not available on Eurostat http://ec.Europa.eu/Eurostat/data/database.

[10]Quarterly domestic data is not available for the cross border positions.

Table 2.3.0.1. – Bank financial structure, loans and output: mean growth rates summary statistics in 10 Euro-zone countries

	Correlations				Mean		CV
	D	**W**	**L**	**GDP**	before crisis	after crisis	
Deposits (D)	1	0.15	0.49	0.15	1.28	0.50	2.71
Wholesale (W)		1	0.54	-0.14	2.30	-0.49	4.23
Loans (L)			1	-0.09	1.65	-0.39	3.17
GDP				1	0.80	0.06	8.36

Note: CV is the coefficient of variation. Before crisis and after crisis correspond to, respectively, before and after (excluded) 2008Q2. Deposits is total deposits from non MFI in the 10 Euro-zone countries considered over the period 1999Q1 to 2014Q4 (640 obs). Wholesale corresponds to bank funds other than deposits to non MFI and bank own funds. Loans is total loans to non MFI. The series are deflated by the chained linked volume GDP implicit deflator. The data is taken from http://www.ecb.Europa.eu.

deposits. Insured funds are less subject to uncertainty and thus typically more stable. All the series' growth rates decreased after the onset of the crisis. The growth rate of wholesale and lending even became negative. Furthermore, the liability item the most correlated with loans is wholesale funds.

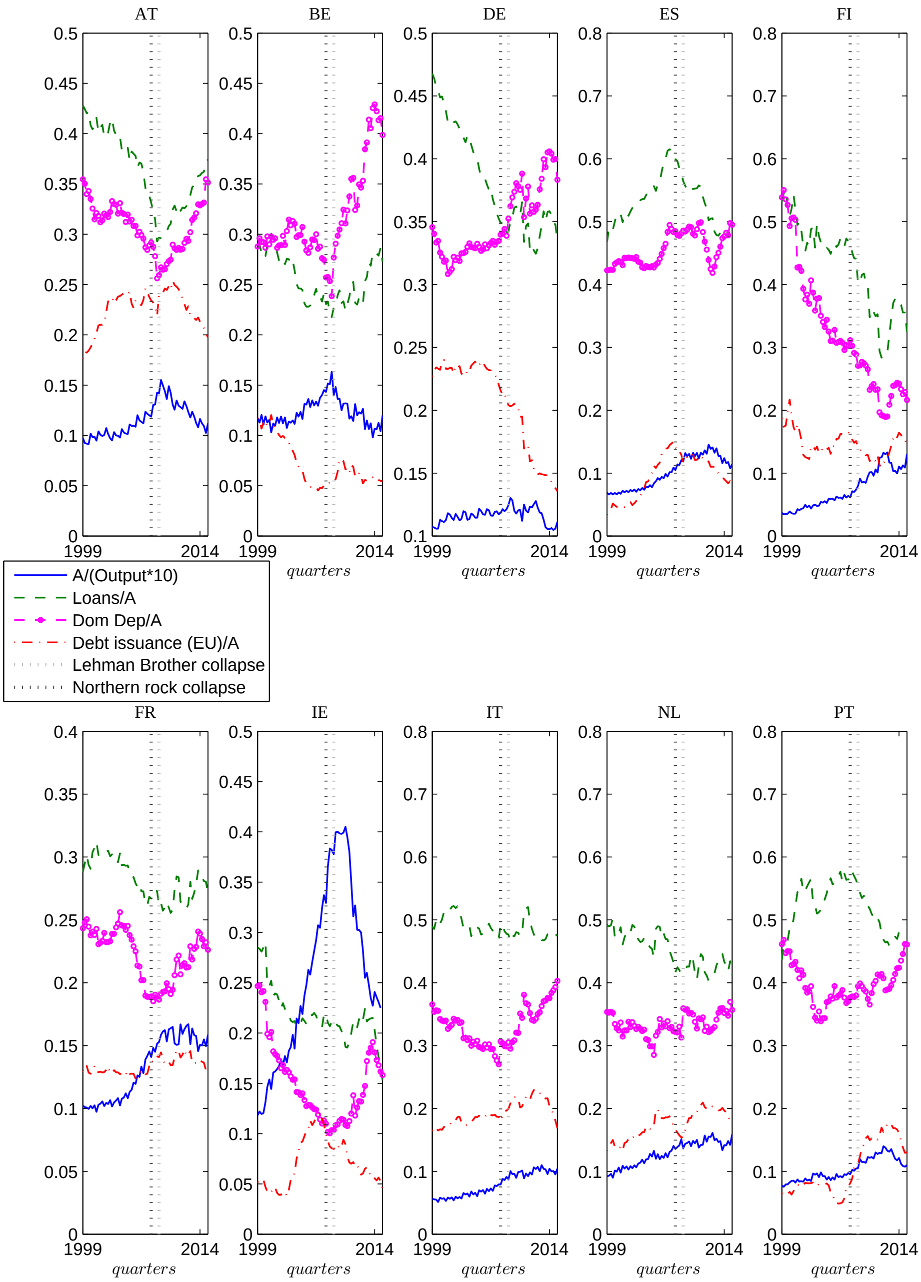
Bank wholesale funds cover Money Market Fund (MMF), bank debt issuance and inter-bank deposits. In this study, I restrict myself to bank debt issuance (held by European Union (EU) residents).[11] The modeling characteristics of the inter-bank market is very different from other markets. MMF shares are already included in the money market and only account only for 1.5% of total liabilities. Bank debt issuance are bank bonds with maturity exceeding two years. Appendix 2.9.A gives summary statistics and a short description of each banks' balance sheet items, as classified by the ECB.[12]

Table 2.3.0.3 reports the growth rates, before and after the crisis, of bank domestic and external liabilities (this includes foreign deposits, from non MFI) and EU and non-EU debt issuance. It also reports their volatility (CV) and their share in total liabilities. Of all, debt issuance (EU) is the most volatile component. It accounts for over 14 % of total banks' funds. In addition, the growth rates of debt issuance (EU), external liabilities and total liabilities have decreased after the Lehman collapse while deposits' growth remained positive.

[11]Banks can target investors and therefore, the decisions to issue debt to other countries' investors may depend on different factors that is not covered in this study.

[12]See also the ECB "Manual on MFI balance sheet statistics", June 2012.

Figure 2.3.0.1. – Banks financial structure evolution



Note: Loans and Deposits correspond to domestic series from http://www.ecb.Europa.eu.

Table 2.3.0.3. – Growth and share of selected liability components

Variable	before	(Std)	after	(Std)	CV	share %
Debt issuance (EU)	.09	(5.80)	-.65	(4.72)	-25.52	14.24
Debt issuance (non-EU)	3.51	(17.33)	1.70	(18.55)	6.46	9.39
Deposits (domestic)	1.28	(2.34)	.51	(2.89)	2.71	31.80
External liabilities	.26	(6.73)	-1.62	(7.18)	-13.46	16.31
Total liabilities	1.98	(3.04)	-.21	(3.89)	3.33	100

Note: CV is the coefficent of variation. Before and after correspond to respectively, before and after 2008Q2. External liabilities includes non Euro area residents' holding of deposits and repurchase agreements, MMF shares and debt securities with maturity of less than or equal to 2 years. Debt issuance includes debt securities with maturity more than 2 years. Domestic deposits are from non MFI. The series are deflated by the chained linked volume GDP implicit deflator. The data is taken from http://www.ecb.Europa.eu.

Figure 2.3.0.1 depicts the evolution of output, domestic loans, domestic deposits from non MFI, and debt issuance (EU) by country, since 1999Q1, given countries' banking sector size. It thus shows the evolution of banking financial structure through time. It also shows the evolution of the banking sector size in countries' total revenue (GDP). The figure reveals a major change in the growth rate of the share of loans after the Lehman collapse in all countries except in IE, IT, NL. The direction of change is however heterogeneous across countries. The share of loans increases in AT, BE, and FR after 2008. It remains stable or decreases in other countries. Nonetheless, the share of domestic loans in total banks' assets is lower in the period after the crisis (relative to before the crisis) in all countries, revealing a change in the asset structure of the Euro-zone banking sector. The Lehman collapse was also suddenly followed by an increase in the share of domestic deposits to non financial institutions in all ten countries except in ES and FI. On the opposite, debt issuance have decreased after the crisis in six out of the ten countries.[13] They have remained nearly constant or increased in other countries. As the share of banks' retail funding in banks' size rose while the share of loans decreased in most countries after the onset of the crisis, I therefore ask: Can the change in the banking sector's asset structure be explained by disruptions on wholesale debt markets?

To assess if there exists a significant relationship between bank debt issuance and bank loans, I estimate an Ordinary Least Squares (OLS) fixed effect regression of domestic loans on bank debt issuance (EU). Table 2.3.0.4 shows the results of the regression before and after the crisis. During both sub-periods,

[13] AT, BE, DE, ES, FI and IE.

Table 2.3.0.4. – Exploratory regression: Loans on debt issuance

OLS with fixed effects		
	(1) Before crisis	(2) After crisis
Dependent variable	Δlog(domestic loans$_{i,t}$)	Δlog(domestic loans$_{i,t}$)
Δlog(debt issuance$_{i,t}$)	.045**	.111***
	(.018)	(.027)
Δlog(total assets$_{i,t}$)	.273***	.347***
	(.056)	(.086)
Constant	.015***	.005***
	(.002)	(.001)
Observations	370	260
R^2	.159	.3447
Ramsey R. test	13.58***	10.26***

Note: The crisis corresponds to 2008Q2. Debt issuance are debt securities held by EU residents. Robust standard errors are in parentheses, * p<.1, ** p<.05, *** p<.01. The Ramsey reset test nul hyp. (H0): There are no non-linear omitted variables.

for a given banking sector size, an increase in bank debt issuance is positively associated with an increase in lending, and more so after the onset of the crisis. Hence, banks' liability structure matters for lending. Furthermore, the Ramsey reset test from the exploratory regression rejects the null hypothesis that the model is well specified. The regression model is hence misspecified, possibly due to non-linear omitted components. In addition, this equation does not give any possible causal interpretation due to endogeneity issues (reverse causality). Indeed, on the one hand, debt issuance of banks may rise due to an increase in the demand for loans. On the other hand, if bank debt funding increases, banks may increase their lending supply.

The next section introduces the theoretical model of Bernanke and Blinder (1988). The model is extended by allowing banks to be funded via wholesale debt funding in addition to deposits. Based on the theoretical framework, I construct in Section 2.5 an equation for the supply of bank wholesale debt. I estimate, using an error correction framework, two instruments for loan supply, money demand shocks as in Driscoll (2004) and Rondorf (2012), and an additional instrument, shocks to the supply of wholesale debt. In section 2.6 and 2.7 I investigate, using both a linear and a non-parametric instrumental variable approach, the role of these financial shocks in affecting loans and output. Section 2.8 concludes.

2.4. An extended Bernanke and Blinder model

The model of Bernanke and Blinder (1988) is a Keynesian macroeconomic model with nominal rigidities where output is demand driven. The novelty of the paper is the introduction of the financial intermediation sector, where financial shocks can affect output via their impact on loans and investment.

2.4.1. Behaviors

There are four markets in this extended IS-LM model: the goods market, the money market, the loans market and the bonds market. By clearing the goods, the money and the loans markets, the bonds market automatically clears by Walras' law. There are also four types of agents: a government, a central bank, a commercial bank, and a set of non bank agents (households and firms). The central bank changes the monetary base $m_{i,t} - p_{i,t}$. The firms finance themselves by issuing bonds at rate r_t and taking loans at rate $\rho_{i,t}$. To the Bernanke and Blinder (1988) model I include the market for bank wholesale long term debt. The balance sheet of banks is displayed in Table 2.4.1.1. On the liability side of their balance sheets, banks hold deposits $m_{i,t} - p_{i,t}$ that are remunerated at the rate $r^d_{i,t}$, and long term debt $W_{i,t}$. They pay an interest rate i_t to debt holders. These interest rates are assumed to be the same across countries. This simplifying assumption is motivated by the fact that cross border bank long term debt transactions are numerous within the Euro-zone. Hence, by non-arbitrage, interest rates should be similar. Banks also hold other liabilities such as own funds, $K_{i,t}$, inter-bank deposits and non EU funds. The size of the banking sector, total liabilities, is denoted $A_{i,t}$. To keep the model tractable I assume other liabilities (own funds, etc.) are exogenous. It can be due, for example, to changes in banking regulation (eg.: the Basel accords). It is assumed banks have an optimal debt structure because, on one hand, wholesale debt funds have factually shorter maturities so they may help meet liquidity needs, are easier to raise than deposits, and are cheaper than capital. On the other hand, they are more prone to macroeconomic instabilities (Gertler et al., 2016). As a consequence, wholesale debt funding is part of banks' investment strategy. On the asset side, banks hold loans $l_{i,t}$ and earn a return $\rho_{i,t}$ on it, and bonds $B_{i,t}$ which yield a return r_t. As on the bank debt market, bonds rates are assumed to be the same across countries. The robustness of the results to this assumption will be tested. Variables are expressed in logarithm except for

Table 2.4.1.1. – Commercial bank balance sheet

Assets	Liabilities
Bonds, $B_{i,t}(r_t)$	Debt issuance, $W_{i,t}(i_t)$
Loans, $l_{i,t}(\rho_{i,t})$	Deposits, $m_{i,t} - p_{i,t}(r^d_{i,t})$
	Other

the interest rates.

On the goods market, total income is a positive function of aggregate consumption and investment, government total expenditure and net exports. Government spending is exogenous. Net exports are assumed to be a function of output and an exogenous exchange rate. Investment is a negative function of financing costs, the bond rate r_t and the lending rate, $\rho_{i,t}$.[14] Consumption also depends negatively on the interest rate on loans and bonds, as an increase in both interest rates raises the cost of goods. By solving for output, the aggregate demand is:

$$y_{i,t} = -\sigma r_t - \alpha \rho_{i,t} + \eta y^*_t + \xi^y_{i,t}. \tag{2.4.1}$$

The variable y^*_t represents components of the aggregate demand that are common to all countries such as government spending and the international environment. The variable $\xi^y_{i,t}$ is a disturbance term to the aggregate demand. It can be due to fiscal policy changes, stock market crashes and booms, or changes in preferences such as changes in confidence or expectations of non-financial agents. If the demand for commodities is insensitive to loans (loans and bonds would be perfect substitute, $\alpha = 0$), (2.4.1) would collapse to the standard IS curve: $y_{i,t} = -\sigma r_t + \eta y^*_t + \xi^y_{i,t}$. Output is increasing in government expenditure and net exports. It is decreasing in the interest rate.

The bond rate r_t is given by the equilibrium between the demand for bonds from households and banks and the supply of bonds from investment firms. It is assumed the bonds market is well integrated in the ten Euro-zone countries such that the return on bonds are the same. Robustness checks to this assumption will be done.

The interest rate on bank loans is determined by the equilibrium between

[14] Driscoll (2004) assumes the interest rate on bonds $r_{i,t}$ is the same for all U.S. states. Interest rates on bonds differ across countries in the Euro-zone (as in Rondorf (2012)). Euro-zone countries bond market is more segmented.

bank loan supply and the demand for loans from firms. On the loans market, the demand for loans is written as:

$$l^d_{i,t} = \tau r_t - \chi \rho_{i,t} + \omega y_{i,t} + \xi^{l^d}_{i,t}, \tag{2.4.2}$$

where $\xi^{l^d}_{i,t}$ is a disturbance term to the loan demand. The demand for loans rises with the costs of the other form of finance, bond issuance, and the revenue, and decreases with its cost $\rho_{i,t}$.

The supply of loans $l^s_{i,t}$ from commercial banks is positively related to deposits $m_{i,t} - p_{i,t}$, own funds $K_{i,t}$, wholesale debt $W_{i,t}$, and negatively to the opportunity cost of lending r_t. It is therefore assumed that deposits and wholesale funds are imperfect substitutes in banks' liabilities. The imperfect substitutability of deposits and wholesale funds arises because deposits are typically more liquid but limited while wholesale funds are more volatile and can be raised more easily. The supply of loans is:

$$l^s_{i,t} = -\lambda r_t + \mu \rho_{i,t} + \beta(m_{i,t} - p_{i,t}) + \zeta W_{i,t} + \zeta_1 K_{i,t} + \xi^{l^s}_{i,t}. \tag{2.4.3}$$

The variable $\xi^{l^s}_{i,t}$ is a disturbance term to the supply of loans. The parameters β, ζ, and ζ_1 take different values due to their different maturity, liquidity and risk characteristics. Indeed, banks hold some non-trivial amounts of capital to hedge themselves against risk (Froot and Stein, 1998). Banks also issue debt to overcome deposit supply constraints (Diamond et al., 2001) and can thus expand their assets.

The supply of deposits is equal to the demand for money. The demand for money is a positive function of revenue $y_{i,t}$ and a negative function of the opportunity cost of holding money, $r_t - r^d_{i,t}$ (investing this money in government bond holding) and $i_t - r^d_{i,t}$ (investing this money in bank wholesale funds). It is thus assumed that bank wholesale funds, deposits (liquid assets) and bonds are imperfectly substitutable in agents' portfolios. The difference arises from maturity, liquidity and risk of each asset. The aggregate equilibrium for money is written

$$m_{i,t} - p_{i,t} = \gamma y_{i,t} - \delta(r_t - r^d_{i,t}) - \delta'(i_t - r^d_{i,t}) + \xi^m_{i,t}. \tag{2.4.4}$$

The variable $\xi^m_{i,t}$ represents state specific shocks to money demand. It can be due to differences in the institutional framework or preferences. For example, differences in the introduction of ATM across countries, differences in the easiness of payment through the internet or credit cards across countries may lead to country specific changes in money demand.

The interest rate on bank debt issuance i_t is determined by the supply and demand for wholesale debt funding of banks. The supply of bank wholesale debt funding is a negative function of deposits $m_{i,t}-p_{i,t}$ as deposits supply constraints lead banks to increase non-deposit liabilities (Diamond et al., 2001). Investment opportunities, reflected through $y_{i,t}$, also affect positively the amount of debt to issue. Total assets $A_{i,t}$ affect positively debt issuance as larger banks are less prone to agency conflicts and asymmetric information (Smith and Warner, 1979) and can therefore be more leveraged. In addition, given banks' size $A_{i,t}$, the supply of wholesale funds is a negative function of country's riskiness (Rixtel et al., 2015), reflected in the interest rate on financial assets r_t, and the volatility on debt markets V_t. Debt issuance is expected to be negatively related to banks' own funds $K_{i,t}$ as it can substitute debt issuance. Alternatively, banks that are more capitalized $K_{i,t}$ are considered less risky and are more able to absorb risk, and can thus issue more bonds (Rixtel et al., 2015; Berger and Bouwman, 2013). The supply is also a decreasing function of its cost i_t. The equation for the supply of wholesale debt funding of banks is the following:

$$W^s_{i,t} = \chi_2 A_{i,t} - \gamma_3 \left(m_{i,t} - p_{i,t}\right) - \chi_1 K_{i,t} - \psi i_t + \beta_1 y_{i,t} + \eta V^*_t - \tau_1 r_t + \xi^{w^s}_{i,t} . \tag{2.4.5}$$

The variable $\xi^{w^s}_{i,t}$ is an exogenous shock to the supply of these funds. It captures variations in the supply for wholesale funds that are not due to economic fundamentals. It could capture, for example, a change in risk perception of banks on the wholesale market, or a change in their preference for liquidity.

Households can invest in wholesale debt securities $W^d_{i,t}$. The demand for wholesale debt is modeled symmetrically to the demand for deposits. It is thus a positive function of output $y_{i,t}$, and a negative function of the opportunity cost of investing in wholesale funds, $r^d_{i,t} - i_t$ and $r_t - i_t$:

$$W^d_{i,t} = -\phi(r_t - i_t) - \phi'(r^d_{i,t} - i_t) + \gamma_1 y_{i,t} + \xi^{w^d}_{i,t} . \tag{2.4.6}$$

The variable $\xi^{w^d}_{i,t}$ is a shock to households preferences for bank wholesale debt. It can arise from a change in market confidence in banks ability to repay its debt.

2.4.2. The relationship between output and loans

To see the innovation of my model with respect to Bernanke and Blinder (1988), one can rewrite the model as follows. Clear the loans market by equating (2.4.2) and (2.4.3), solve for $\rho_{i,t}$, and, then, plug the result in (2.4.1),

$$\begin{aligned} y_{i,t} &= \frac{1}{1+\frac{\omega\alpha}{\chi+\mu}}\{-\left[\sigma+\frac{\alpha\left(\tau+\lambda\right)}{\left(\chi+\mu\right)}\right]r_t+\eta y_t^*+\xi_{i,t}^y \\ &\quad +\frac{\alpha}{\chi+\mu}\left[\xi_{i,t}^{l^s}+\zeta W_{i,t}+\zeta_1 K_{i,t}+\beta\left(m_{i,t}-p_{i,t}\right)-\xi_{i,t}^{l^d}\right]\}. \quad (2.4.7) \end{aligned}$$

By assuming that bonds and loans are imperfect substitutes, Bernanke and Blinder (1988) model permits monetary policy to affect output through a change in loan supply ($\alpha \neq 0$ and $\beta \neq 0$), i.e. allows for an effective bank lending channel. Since it is assumed that bank deposits and wholesale funds are imperfect substitutes ($\zeta \neq 0$), wholesale debt can have real effects as well. Thus, my assumption extends the bank lending channel to a “bank wholesale funding channel”.

To see the relation between output and loans, the system of equations (2.4.1), (2.4.2), (2.4.3), (2.4.4), (2.4.5), and (2.4.6) can be rewritten in the following way. For simplicity it is assumed $r_{i,t}^d = 0$, as in Rondorf (2012). First, solve for $\rho_{i,t}$ in (2.4.2) and then plug the result in the aggregate demand (2.4.1):

$$y_{i,t} = \frac{1}{1+\frac{\alpha}{\chi}\omega}\left\{-\left(\sigma+\frac{\alpha}{\chi}\tau\right)r_t+\frac{\alpha}{\chi}l_{i,t}+\eta y_t^*-\frac{\alpha}{\chi}\xi_t^{l^d}+\xi_{i,t}^y\right\}. \quad (2.4.8)$$

Loans affect output if loans and bonds are imperfectly substitutable, i.e. if $\alpha \neq 0$. Then, in (2.4.3), replace $m_{i,t}-p_{i,t}$ by its value in (2.4.4), $\rho_{i,t}$ by its value in the loan demand (2.4.2), $W_{i,t}^s$ by its value in (2.4.5), and solve for i_t by clearing the wholesale funds market such that equation (2.4.5) is equal to (2.4.6). Assume that capital is a fraction ν of total assets and that the level of capital is exogenous, given by country specific regulations and characteristics.[15]

[15] The Basel regulation imposes that capital should be a fraction of risky assets. Here, I assume all assets are risky.

Finally, solve for loans l $(l^s_{i,t} = l^d_{i,t})$,[16]

$$l_{i,t} = c_1 r_t + c_2 \xi^m_{i,t} + c_3 \xi^{w^s}_{i,t} + c_4 V^*_t + c_5 y_{i,t} + c_6 \xi^{l^s}_{i,t} + c_7 \xi^{l^d}_{i,t} + c_8 K_{i,t}. \quad (2.4.9)$$

If banks' financial structure does not matter for lending because banks can perfectly offset the reduction in one type of funds by another, then the coefficients $\beta = \zeta = \zeta_1 = 0$, and thus $c_2 = 0$. Then, the bank lending channel is not effective and money demand shocks $\xi^m_{i,t}$ have no effect on loans. Furthermore, the coefficient $c_3 = 0$ and wholesale funding shocks $\xi^{w^s}_{i,t}$ have no effect on loans neither.

Equation (2.4.8) shows that output is affected by credit and by the interest rate on government bonds, r_t. The interest rate r_t captures the liquidity preference channel. However, (2.4.9) suggests that loans might also be explained by output. Loans are thus endogenous to output.

Define centered variables as $\tilde{x}_{i,t} = x_{i,t} - (1/N) \sum_{i=1}^{N} x_{i,t}$. By demeaning all variables by their cross sectional mean, the common effects to all countries are eliminated. The interest rate channel (since the model concerns a monetary union, the central bank cannot target a specific state) as well as any Euro-zone wide shocks (such as oil shocks) are eliminated. In particular, potential common non-linear effects (such as threshold effects) are eliminated. As a consequence, only country specific variations (linear or non-linear) remain. The shocks $\xi^j_{i,t}$, $j = \{m, w^s, w^d, l^s, l^d, y\}$ are idiosyncratic. The equations (2.4.8) and (2.4.9) with cross-sectionally centered variables are

$$\tilde{y}_{i,t} = \frac{1}{1 + \frac{\alpha}{\chi}\omega} \left\{ \frac{\alpha}{\chi} \tilde{l}_{i,t} - \frac{\alpha}{\chi} \xi^{l^d}_t + \xi^y_{i,t} \right\}, \quad (2.4.10)$$

$$\tilde{l}_{i,t} = c_2 \xi^m_{i,t} + c_3 \xi^{w^s}_{i,t} + c_5 \tilde{y}_{i,t} + c_6 \xi^{l^s}_{i,t} + c_7 \xi^{l^d}_{i,t} + c_8 \tilde{K}_{i,t}. \quad (2.4.11)$$

In (2.4.10) loans are correlated with the error terms $\xi^{l^d}_{i,t}$ and $\xi^y_{i,t}$. The variable $\tilde{l}_{i,t}$ is endogenous to $\tilde{y}_{i,t}$ and, as a consequence, the coefficient on loans $\tilde{l}_{i,t}$ in (2.4.10) is biased. To deal with endogeneity issues, I use an instrumental variable

[16] where $c_0 = \chi/(\chi + \mu)$, $b_0 = \gamma_3\gamma + \gamma_1 - \beta_1$ $a_1 = 1/[(\phi + \phi') + \psi - \gamma_3\delta']$, $a_2 = \phi - \tau_1 + \gamma_3\delta$, $b = \zeta(\phi - \phi') - \beta\delta'$, $c_1 = c_0[-\lambda + \tau\mu/\chi - \delta\beta - \phi\zeta + a_1 a_2 b]$, $c_5 = c_0[\omega\mu/\chi + \gamma\beta + \gamma_1\zeta - b_0 a_1 b]$, $c_2 = c_0(\beta - a_1\gamma_3 b)$, $c_3 = c_0 a_1 b$, $c_4 = \eta c_0[\zeta - a_1 b]$, $c_6 = c_0$, $c_7 = c_0\mu/\chi$, and $c_8 = \nu c_0 \chi_2 a_1 b - \chi_1 a_1 b + \zeta_1$.

approach. Assuming $Corr(\xi^m_{i,t}, \xi^{l^d}_t)$ =$Corr(\xi^m_{i,t}, \xi^y_{i,t}) = 0$ and $Corr(\xi^{w^s}_{i,t}, \xi^{l^d}_{i,t}) = Corr(\xi^{w^s}_{i,t}, \xi^y_{i,t}) = 0$, the shocks to preferences for deposits $\xi^m_{i,t}$ and the shocks to bank debt issuance $\xi^{w^s}_{i,t}$ become obvious choices of instruments and, therefore, loan supply effects can be identified. These variables are correlated with loans but not with the error in (2.4.10). This allows the system to be (over) identified. The assumption on the correlations is reasonable since both money demand shocks and bank debt issuance shocks are independent of real output $y_{i,t}$. My contribution with respect to Driscoll (2004) rests in the variable $\xi^{w^s}_{i,t}$. This variable is a second instrument for loan supply. Alternatively, one could also assume $Corr(\xi^{l^s}_{i,t}, \xi^y_{i,t}) = Corr(\xi^{l^s}_t, \xi^{l^d}_{i,t}) = 0$ so that shocks to the supply of loans $\xi^{l^s}_{i,t}$ can also be an instrument for loans in (2.4.10). The disturbance $\xi^{l^s}_{i,t}$ measures, for example, changes in bank regulation (Basel II, III for example).

Then, the two simultaneous equations (2.4.10) and (2.4.11) between $\tilde{y}_{i,t}$ and $\tilde{l}_{i,t}$ are:

$$\tilde{y}_{i,t} = s_1 \tilde{l}_{i,t} + e_{1,i,t}, \tag{2.4.12}$$

$$\tilde{l}_{i,t} = s_2 {\xi^m}_{i,t} + s_3 \tilde{r}_{i,t} + s_4 \xi^{w^s}_{i,t} + e_{2,i,t}. \tag{2.4.13}$$

This system will be estimated in a 2SLS estimation. The error terms in the two stages are called $e_{1,i,t}$ and $e_{1,i,t}$. The first stage of the instrumentation (2.4.13) verifies if country specific money demand shocks $\xi^m_{i,t}$ and/or variation in bank preferences for debt issuance $\xi^{w^s}_{i,t}$ affect country specific loan variation, $\tilde{l}_{i,t}$. Coefficients s_2 and s_4 statistically different from zero would imply that banks' financial structure matters for lending. A value $s_2 \neq 0$ argues in favor of the bank lending channel while $s_4 \neq 0$ argues in favor a wholesale funding channel effect. The second stage verifies if country specific loan variation, instrumented by idiosyncratic shocks to bank funds, affect countries' output growth. It also suggests that firms rely on bank credit for investment.

The next section presents how shocks to bank fundings are constructed and estimated.

2.5. Estimation of financial shocks

This section unveils the computation of the two financial shocks: shocks to money demand and shocks to bank long term debt issuance. First, the empirical strategy to estimate money demand is presented. Then, the strategy to estimate bank long term debt issuance is exposed.

2.5.1. Money demand shocks

The shocks to money demand $\xi^m_{i,t}$ are measured as residuals from the money demand equation (2.4.4). Appendix 2.9.B shows that, at a 90% confidence level, the variables in the regression are integrated of order one, that is, all series are stationary once first differenced. Therefore, money demand is best modeled in an error correction framework, where short and long run deviations can be simultaneously estimated. Compared to regressions in levels, it avoids possible spurious correlation of highly trended variables. Using first differences would omit the long run relationships between variables, and the omitted long run variables would then be captured in the error term. Then, estimated money demand shocks would be biased and the model would be misspecified.

Therefore, I estimate (2.4.4) using an error correction framework, augmented with a lagged dependent term, as in Rondorf (2012). The model is based on Pesaran and Shin (1999). The short and the long run dynamics are assumed to be the same across countries.

Fixed effects are included in the regression as they allow to account for the long run heterogeneity of countries (such as different trends).[17] The Nickell bias (Nickell, 1981) arises in dynamic panel data models with fixed effects. The inclusion of a fixed effect term combined with the dependent lagged variable in the set of explanatory variable creates a correlation between the error term and the lagged dependent variable. Therefore, the coefficient will be biased. Here, the Nickell bias can be neglected because the time series length is large (T=64) and the cross section length relatively small (N=10 countries). The Akaike Information Criterion (AIC) criterion suggests taking two lags of each variable.[18]

The model to be estimated is a dynamic fixed effect model:

$$\Delta\tilde{Y}_{i,t} = \mu_i - c_0\tilde{Y}_{i,t-1} + c_1\tilde{X}_{i,t-1} + c_2\Delta\tilde{Y}_{i,t-1} + \sum_{s=0}^{1} c_3\Delta\tilde{X}_{i,t-s} + \xi^m_{i,t}, \qquad (2.5.1)$$

[17]The Hausman test strongly rejects the null hypothesis according to which there is no fixed effect. The statistic is $\chi^2(5) = 31.02^{***}$ over the whole period studied.

[18]The Akaike criterium was chosen with maximum lag order four.

where the variable $\tilde{Y}_{i,t}$ is the dependent variable $(\tilde{m}_{i,t} - \tilde{p}_{i,t})$ and $\tilde{X}_{i,t}$ is the set of explanatory variables in the centered money demand equation (2.4.4). The variables μ_i denotes country specific fixed effects. The ratio c_1/c_0 corresponds to the long run income elasticity of money demand.

The Euro-zone is a common monetary union and the interest rate is considered exogenous for each country.[19] Hence, the IS-LM model predicts that any shock to money demand in one country is automatically accommodated, so that output is left unchanged. Real balances increase in this country and decrease in all others. Hence, any country specific shock to money demand is translated into higher deposits. Therefore, the endogeneity problem between output and money in the money demand equation is, in theory, mitigated. However, under the hypothesis of a lending channel, so that money demand shocks and output are correlated,[20] the estimated coefficients associated with current output in the money demand estimation will be biased. To avoid the potential bias, contemporaneous output growth in (2.5.1) is instrumented.

To confront endogeneity issues with an instrumental variable approach, two conditions have to be met. First, the instrument has to be sufficiently correlated with the endogenous variable. Second, the instrument has to explain the dependent variable, money growth, only through the endogenous variable, output growth, and must be uncorrelated with the error term in (2.5.1). I instrument output growth by the contemporaneous level of exports, cross-sectionally centered, $\tilde{X}_{i,t}$. A high level of exports exposes a country to foreign activity, increasing economic fluctuations. In addition, I postulate that they explain the level of money only through output growth.

A two stage least square (2SLS) robust fixed effect estimation technique is implemented. This is the baseline specification. In the first stage, I regress output growth on all exogenous variables in money demand and the instrument, $\tilde{X}_{i,t}$. Then, the predicted value from the first stage is used instead of output growth, the endogenous variable. Appendix 2.9.C presents the results of the 2SLS estimation of money demand (2.5.1) from 1999Q1 to 2008Q2 and from 1999Q1 to 2014Q4 in the ten Euro-zone countries. It also displays the results of the money demand estimation, with no instrumentation of output growth. As a robustness check to the assumption on the equality of bond rates r_t in

[19] Consider small open economies with fixed exchange rates.

[20] Deposits in country i will change loans in the country. When firms are bank dependent, investment and output are also affected.

the Euro-zone, the estimation with heterogeneous bond rates are also reported. The country specific bond rates are then measured by the ten year government bond yield.

Concerning the first stage of the 2SLS money demand estimation, the F test is larger than the threshold level of 10 given by the "rule of thumb" (Staiger and Stock, 1997), which indicates that the instrument is sufficiently correlated with the endogenous variable. Therefore, exports are strong instruments.

Turning to the estimation of the money demand, the coefficients associated with the error correction terms confirm the cointegration relationship in all specifications, when output is or is not instrumented by exports. The error correction term suggests that the rate of convergence of variables to their long run trend is slow. The magnitude of the long run coefficients on output, interest rates and the error correction term are in line with earlier contributions on the Euro-zone money demand (Rondorf, 2012). Regression (II), the regression in which bond rates are heterogeneous, corresponds to the exact specification in Rondorf (2012). Over the same period of estimation, in the pre-crisis period, the coefficient associated with the long run effect of output and interest rates are the same. The long run output elasticity of money demand is 1.84. The speed of adjustment is 0.08. The coefficients in Rondorf (2012) are respectively, 1.44 and 0.09. Before the crisis, the long run interest rate semi-elasticity of money demand has the right sign but is not significant. The small differences in results may be attributed to the revision of the data. When output growth is instrumented, there are slightly higher long run elasticities of output.

In the baseline specification (I), before the crisis, the long run income elasticity of money demand is 1.58. It is 1.41 over the whole period. The short run estimates of output growth are not significant, while they are when output growth is not instrumented. This possibly indicates that there was indeed an endogeneity issue.

As shown in Appendix 2.9.G, the residuals in the money demand are equally spread around the zero line.

2.5.2. Bank debt issuance shocks

In the extension of Bernanke and Blinder (1988) model developed above, the determinants of bank long term debt issuance are described by

$$\tilde{W}^{s}_{i,t} = \chi \tilde{A}_{i,t} + \beta_1 \tilde{y}_{i,t} - \chi_1 \tilde{K}_{i,t} - \gamma_3 \left(\tilde{m}_{i,t} - \tilde{p}_{i,t}\right) + \xi^{w^s}_{i,t}. \tag{2.5.2}$$

The set of country specific determinants used in the regression of bank debt issuance are similar to the ones in Rixtel et al. (2015)' country specific regression, once variables are centered around their cross sectional mean, with a two exceptions. First, they do not include total deposits in their country specific analysis due to data limitations. Second, bank stock market value is used as a regressor in their country analysis. The authors argue that larger values of bank stocks increase bank equity issuance and, thus, banks can issue more bonds (since they can absorb risk better, see Rixtel et al. (2015)). Equity is considered exogenous in my theoretical model.

Appendix 2.9.B shows that, at a 90% confidence level, the variables in the regression are integrated of order one, that is, all series are stationary once first differenced. Short and long run deviations should be simultaneously estimated to capture an unbiased error term, used to measure the shocks, $\xi^{w^s}_{i,t}$. Hence, in contrast with Rixtel et al. (2015), I estimate (2.5.2) using a dynamic fixed effect model in which all (semi) elasticities are the same for all countries, as in the model for the money demand (2.5.1). Fixed effects are included as the Hausman test strongly rejects the null hypothesis that there should not be fixed effects in the dynamic model.[21] Two lags of each variable are included according to the AIC.[22]

Note that I assume that both output growth and asset growth, affect the short run deviations of bank debt issuance. Indeed, Adrian and Shin (2010) argue that commercial banks target a fixed leverage ratio. Banks that grow faster issue more debt due to leverage targeting.[23] Hence, the growth of bank leverage and the growth of bank assets are strongly positively correlated. Furthermore, debt leverage is pro-cyclical, suggesting that debt increases during booms and decreases during crises (Adrian et al., 2012). This is in contrast with Rixtel et al. (2015) who assume both variables affect the long run level of bank debt issuance.

Appendix 2.9.D reproduces the baseline country level regression in Rixtel et al. (2015), before the Lehman collapse, using country level data. It compares

[21] The statistic $\chi^2(14)$=43.01*** from 1999Q1 to 2014Q4. It is $\chi^2(17)$=42.19** when I use country specific interest rate on bonds.

[22] The Akaike criterium was chosen with maximum lag order four.

[23] Marsh (1982) also shows that firms in the UK tend to target debt levels.

the results with the ones estimated in Rixtel et al. (2015), in which they use the sum of debt issuance over a sample of banks per country. Except for total assets, the regressions display disparate results. The differences are attributable to the missing variables (bank stock$_{i,t}$ is not included due to data limitations) and to the differences in the sample of banks. During the period 2005 to the end of 2013, the sum of assets of their selected sample is only one fifth of the ten country sample. Moreover, between 2005 and 2008, debt issuance represents 1% of total assets in their bank level sample while it represents 15% in my country level sample. Given these major differences, using country level data, the explanatory power of the regression is poor, and most variables are not significantly different from zero. This further motivates the use of an alternative empirical specification.

In addition to differences in the modeling and the inclusion of variables, an endogeneity bias between debt issuance and output is considered. Indeed, reverse causality problems may arise. Banks may reduce wholesale debt because economic activity is low. Moreover, a fall in bank debt issuance reduces investment opportunities and thus may reduce economic activity.

As in the money demand, an instrumental variable approach with 2SLS is used to correct for endogeneity. In the first stage I regress output growth on some instruments and the exogenous variables in (2.5.2). The second stage regresses bank debt issuance on the predicted value of output growth from the first stage.

The instruments must satisfy the condition of sufficient correlation and exogeneity noted earlier. Output growth is instrumented with five instruments: the second lag of output growth, $\Delta\tilde{y}_{i,t-2}$, current and lagged level of exports, $\tilde{X}_{i,t}$ and $\tilde{X}_{i,t-1}$, and by the first and third lag change of the domestic credit to GDP gap ratio (Δgap_t, Δgap_{t-3}). The second lag of output growth is expected to be correlated with contemporaneous output growth. It is less likely that bank debt issuance affects past levels of output, although it is not excluded that, output falls due to an expected decrease in future bank debt issuance. Lagged and current levels of exports are highly correlated with output, and should explain bank debt issuance only through their increase in economic activity. The variable gap_t is the change in the ratio of credit to output from its long run trend, as measured by the European Systemic Risk Board (ESRB). It measures either excessive growth or low output growth and, is therefore a country specific indicator of macro-economic vulnerabilities. This variable is considered as a reliable early warning indicator for crises (Alessi and Detken, 2014). Therefore, Δgap_t should measure the speed at which excessive credit growth changes. It is expected to be highly related to future output growth. In an alternative scenario, it is possible that the speed at which lending grows raises bank liquidity or maturity concerns, and leads to a change in bank debt issuance. However, the validity of an instrument requires that it is correlated with the dependent variable only through the endogenous variable. Given the five instruments and the single endogenous variable, the model is said to be *over-identified*. Endogeneity test can then be constructed for the instruments and determine if the instruments are uncorrelated with the error term in the structural equation of debt issuance on output (test for over-identifying restrictions).

The Hansen J test, displayed in Appendix 2.9.E together with the first stage results, gives confidence that the set of instruments are valid. According to the Hansen J test, I do not reject the null hypothesis that the set of instruments are jointly uncorrelated with the error term.[24] The Kleibergen-Paap Wald rk F statistic is also reported. This statistic is the robust counterpart of the F test with multiple endogenous variables (Cragg-Donald Wald test). This value is less than the threshold value of 10, given by the "rule of thumb" (Staiger and Stock, 1997), indicating that the instruments are weak, in all the regressions. Since the relevance of the instruments is questionable, the remainder of this chapter presents the results, with and without the instrumentation of output.

Table 2.5.2.1 displays the results from the estimation of bank debt issuance determinants, from 1999Q1 to 2014Q4. In the baseline specification (I), I correct for the endogeneity of output. Specification (II) presents the results in which output is not instrumented. In the second column of each specification, I test the robustness of the results to the equality of bond rates in the Euro-zone. Appendix 2.9.E shows the estimates of bank debt issuance determinants before the crisis.

The coefficients associated with assets, deposits, and output in the long run, and asset growth are larger once the endogeneity bias is potentially corrected for, suggesting that there was a downward bias on these variables. The long run elasticity of capital decreases once output is instrumented. In addition, the long run level of output becomes significant while output growth is no longer

[24]More precisely, we cannot reject the null hypothesis that the over-identifying restrictions are valid.

significant.

Table 2.5.2.1. – Debt determinants (1999Q1-2014Q4)

Dynamic Fixed Effects	Dependent variable: $\Delta\tilde{W}_{i,t}$ Second stage (I)		No instrumentation (II)	
Error correction	-.033***	-.031***	-.027***	-.026***
	(.009)	(.009)	(.005)	(.004)
$(\tilde{m}_{i,t-1} - \tilde{p}_{i,t-1})$	-.113***	-.122***	-.090*	-.096*
	(.035)	(.037)	(.045)	(.047)
$\tilde{A}_{i,t-1}$	.072***	.069***	.065***	.062***
	(.022)	(.023)	(.016)	(.014)
$\tilde{K}_{i,t-1}$	-.020*	-.017	-.031**	-.028**
	(.011)	(.011)	(.013)	(.012)
$\tilde{y}_{i,t-1}$	.193**	.178**	.145	.134
	(.080)	(.083)	(.111)	(.108)
$\tilde{r}_{i,t-1}$		-.001		-.000
		(.001)		(.001)
$\Delta\tilde{y}_{i,t}$	-.439	-.454	.571*	.550**
	(.828)	(.787)	(.260)	(.226)
$\Delta\tilde{y}_{i,t-1}$	.027	-.007	.270	.239
	(.302)	(.296)	(.213)	(.177)
$\Delta\tilde{A}_{i,t}$	.467***	.473***	.411***	.418***
	(.081)	(.079)	(.126)	(.126)
$\Delta\tilde{A}_{i,t-1}$	-.031	-.037	-.045	-.049
	(.082)	(.081)	(.057)	(.057)
$\Delta(\tilde{m}_{i,t} - \tilde{p}_{i,t})$	.140	.126	.129	.118
	(.150)	(.147)	(.093)	(.091)
$\Delta(\tilde{m}_{i,t-1} - \tilde{p}_{i,t-1})$	-.297***	-.296***	-.322***	-.321***
	(.075)	(.074)	(.055)	(.047)
$\Delta\tilde{K}_{i,t}$	-.051	-.048	-.057	-.055
	(.050)	(.049)	(.047)	(.050)
$\Delta\tilde{K}_{i,t-1}$	-.017	-.029	-.011	-.022
	(.037)	(.038)	(.042)	(.039)
$\Delta\tilde{r}_{i,t}$		-.004***		-.004*
		(.002)		(.002)
$\Delta\tilde{r}_{i,t-1}$		.006***		.005***
		(.002)		(.001)
$\Delta\tilde{W}_{i,t-1}$	.368***	.367***	.381***	.381***
	(.050)	(.050)	(.050)	(.053)
Constant			.000	.000
			(.000)	(.000)
Observations	600	600	620	620
log(likelihood)	1155.99	1160.51	1202.33	1206.74
R^2	.315	.325	.339	.348

Note: * p<.1, ** p<.05, *** p<.01. Robust standard errors are in parenthesis. $\tilde{x}_{i,t} = x_{i,t} - (1/N)\sum_{i=1}^{N} x_{i,t}$, where $x_{i,t}$ is deflated per capita and in log, except for the interest rates.

The error correction term is negative and highly statistically significant in all the specifications of Table 2.5.2.1, indicating that debt issuance responds to deviations from the long run equilibrium. It confirms that there is a cointegrating relationship between the variables such that they converge to the same long term trend. The speed of adjustment of the short run deviations from their long run trend is slow. It is equal to -0.033 in the benchmark estimation, the first column of specification (I). The coefficient associated with deposits level $\tilde{m}_{i,t-1} - \tilde{p}_{i,t-1}$ has the expected sign. It is negative, large and statistically significant. Therefore, deposit supply constraints, in the long run, do affect bank debt issuance choice. Bank debt issuance is positively correlated with countries' wealth $\tilde{y}_{i,t-1}$. This evokes that banking sectors in wealthier countries vary their debt by more. The elasticity of bank long run own funds $\tilde{K}_{i,t-1}$ is negative, indicating that capital and debt issuance are substitutes in banks' financing choice rather than complements. The growth of total assets $\Delta\tilde{A}_{i,t}$ is positively and significantly associated with bank debt issuance. It supports the leverage targeting theory according to which banks raise relatively more debt when they grow more quickly. In addition, total assets is positively correlated with bank debt issuance, supporting the asymmetric information theory predicting a positive relationship between bank debt issuance and bank size. The lagged variation of debt issuance is highly significant and positive, suggesting that there is some persistence in banks' debt issuance. Banking sectors that raised debt yesterday are more likely to do so today. Finally, the R^2 statistic shows that 32% of the variance of bank debt issuance variation is explained by the model in which output is instrumented.

The second column of specification (I) and the second column of specification (II) of Table 2.5.2.1 show that the results are robust to the hypothesis on country specific differences in bond rates. The estimated speed of adjustment to the long run trend remains very similar. The size and significance of variables are the same as in the benchmark estimation with one exception in the 2SLS specification (I), the level of capital no longer affects bank debt issuance. It is not excluded that capital is related to the change in risk on markets, when interest rates are not included in the regression. The columns also show that short run variations in the interest rate on bonds negatively affect debt issuance. The coefficients on the variation of bond rates are statistically different from zero. This indicates that country specific interest rates on the bonds market are important short run determinants of long run bank debt issuance. Thus, low interest rates variations are associated with higher risk taking and more debt issuance.

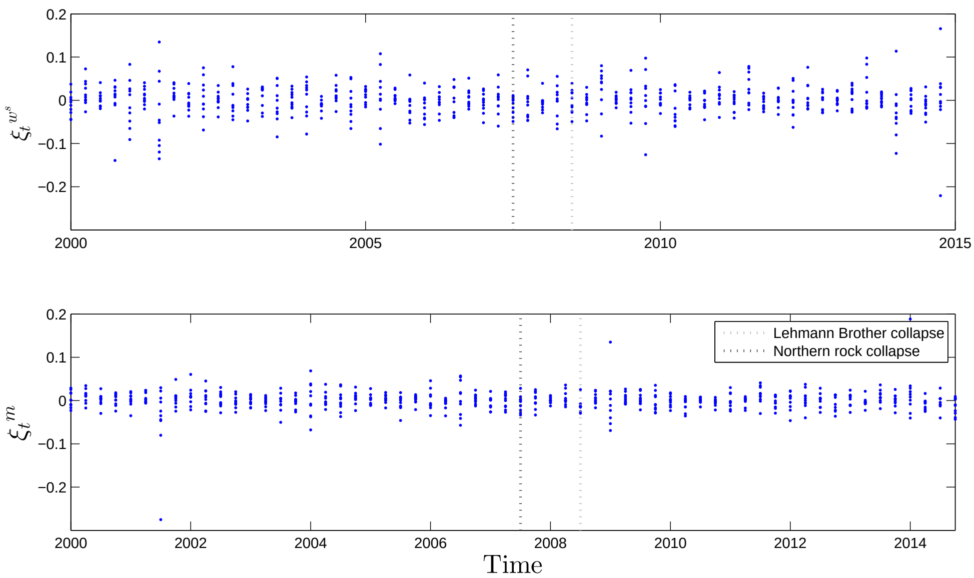
Appendix 2.9.E shows that all the results hold before the crisis. The size and significance of the (semi) elasticities are stable, with the exception that output and capital levels do not significantly affect bank debt issuance.

Appendix 2.9.G also assesses the model adequacy through the plot of the residuals against the predicted values in all of the regressions, both before the crisis and including the whole sample. The residuals are spread approximately equally across the predicted dependent variable with some large values, in both periods studied. Nevertheless, there is no systemic pattern.

2.5.3. Analysis of shocks

Figure 2.5.3.1 graphs the residuals of bank debt issuance $\xi_t^{w^s}$ and money demand shocks ξ_t^m through time, considering the baseline specification, hence, with output instrumented, and bond rates equal across countries, estimated over the whole time frame. The shocks are spread equally around the zero line and their variance is homogeneous along the timeline, except for some isolated points. The variance of money demand shocks ξ_t^m through time is, on average, smaller than the variance of the debt issuance shocks $\xi_t^{w^s}$.

Figure 2.5.3.1. – Financial shocks



2.6. Results, linear estimation

This section investigates the relationship between loans supply and output. I first present the linear estimation of output on loans. I then present the results from the 2SLS estimation, in which shocks to bank debt issuance and bank deposits are used as instrumental variables. These shocks are measured by residuals from the dynamic panel estimations of the money demand and the bank debt issuance.

Appendix 2.9.B shows that loans and output are non-stationary. Hence, I take first differences of variables. According to the Hausman test, fixed effects are included in all the regressions. Indeed, fixed effects can capture country specific variations that are not taken into account by other variables in the model. For example, they can capture the different trends in output growth of the different countries. In addition, as indicated by the country specific AIC, two lags are included in the regressions.[25] It reflects the fact that the macroeconomic series of output and loans adjust slowly.

Table 2.6.0.1 verifies the relationship between output and bank loans. Columns (a) correspond to the regressions in which government bond rates are considered to be the same in all countries. Columns (b) show the regressions in which heterogeneous bond rates have been included. Before the Lehman collapse, the first lag of loan growth is statistically and positively correlated with output growth. Over the whole period (until 2014Q4), lending is significantly and positively correlated with output. The coefficient on the second lag of loans is negative, and statistically significant. In the specification (a), an increase in the contemporaneous growth rate of loans above the Euro-zone mean of one percentage point in country i corresponds to an increase in the growth rate of real GDP by .057 percentage points above the Euro-zone average. Since the growth rate of real GDP per capita is on average 0.2% during the whole period studied and since loans vary by 1.6 percentage points around the average, loan variation can have rather important effects on output growth. However, the estimates are likely to be biased due to reverse causality problems. Both demand and supply effects can affect the correlation between bank credit and output. Therefore, this regression does not allow one to conclude that causality effects resulted.

To control for the endogeneity of loans, I use a 2SLS estimation with two

[25]The Akaike criterium was chosen with maximum lag order four.

Table 2.6.0.1. – OLS regression of output on loans

OLS with FE	Dependent variable: $\Delta\tilde{y}_{i,t}$			
	(a)	(b)	(a)	(b)
	1999Q1-2008Q2		1999Q1-2014Q4	
$\Delta\tilde{l}_{i,t}$	-.029	-.034	.057**	.059*
	(.023)	(.025)	(.025)	(.028)
$\Delta\tilde{l}_{i,t-1}$	.033*	.032**	.034	.033
	(.017)	(.014)	(.021)	(.020)
$\Delta\tilde{l}_{i,t-2}$	-.045	-.034	-.057**	-.055**
	(.026)	(.028)	(.021)	(.022)
$\Delta\tilde{y}_{i,t-1}$	-.344***	-.338***	-.197***	-.205***
	(.064)	(.054)	(.055)	(.055)
$\Delta\tilde{y}_{i,t-2}$	-.105**	-.106***	.022	.014
	(.037)	(.030)	(.036)	(.036)
$\Delta\tilde{r}_{i,t}$		-.001		-.001
		(.005)		(.001)
$\Delta\tilde{r}_{i,t-1}$		-.010		.000
		(.008)		(.001)
$\Delta\tilde{r}_{i,t-2}$		-.001		-.000
		(.004)		(.000)
Constant	-.000***	-.000***	.000***	.000***
	(.000)	(.000)	(.000)	(.000)
Observations	350	350	610	610
R^2	.109	.126	.063	.068

Note: * p<.1, ** p<.05, *** p<.01. Robust standard errors are in parenthesis. Variables are described in Table 2.5.2.1.

instruments. Section 2.4 shows that shocks to money demand $\xi^{m}_{i,t}$ and shocks to bank long term debt funding $\xi^{w^s}_{i,t}$ can theoretically be used as instruments for loan supply. The coefficients to be estimated are said to be over-identified as there is one endogenous variable and two instruments. This is in contrast with Driscoll (2004) and Rondorf (2012), who use only shocks to money demand as an instrument. As noted in Section (2.5), instrumentation helps to deal with endogeneity issues if they satisfy two conditions, sufficient correlation and exogeneity.

Adding instruments allows to increase the precision of the estimates, and to improve the 2SLS estimator efficiency. The literature suggests that unstable bank liability items such as wholesale funds are important determinants of loan supply. Furthermore, over-identification allows for the construction of an endogeneity test for the instruments and determine if the instruments are uncorrelated with the error term in the structural equation of output on loans (test for over-identifying restrictions). Nevertheless, it is important to make sure that the additional instrument is sufficiently correlated with the endogenous variable, since weak instruments increase the bias of the 2SLS estimator. The definition for sufficient correlation is developed in Staiger and Stock (1997). It defines a threshold level for F-test values such that instruments are considered as weak.

Tables 2.6.0.2 and 2.6.0.3 present the results from, respectively, the first and the second stage linear estimation. The baseline regression (I) consider financial shocks that are constructed instrumenting output growth. Specification (II) does not consider endogeneity issues between output and money and output and bank debt issuance.

Table 2.6.0.2. – First stage IV regression: Loans on financial shocks

OLS with FE	Dependent variable: $\Delta\tilde{l}_{i,t}$			
	Instrumentation (I)		No instrumentation (II)	
	(99Q1-08Q2)	(99Q1-14Q4)	(99Q1-08Q2)	(99Q1-14Q4)
${\xi^{m}}_{i,t}$	.093***	.035	.113***	.037
	(.023)	(.027)	(.027)	(.027)
${\xi^{m}}_{i,t-1}$	-.048*	.014	-.046*	.016
	(.022)	(.016)	(.025)	(.016)
${\xi^{m}}_{i,t-2}$	-.002	.059**	-.002	.064**
	(.020)	(.020)	(.023)	(.022)
${\xi^{w^s}}_{i,t}$	.054**	.087**	.045***	.068***
	(.018)	(.035)	(.011)	(.021)
${\xi^{w^s}}_{i,t-1}$	.028	.034*	.036	.036*
	(.025)	(.016)	(.022)	(.018)
${\xi^{w^s}}_{i,t-2}$	.025	.030	.021	.029
	(.019)	(.029)	(.028)	(.033)
$\Delta\tilde{y}_{i,t-1}$	-.028	-.043	-.004	.013
	(.111)	(.064)	(.120)	(.047)
$\Delta\tilde{y}_{i,t-2}$	-.286**	-.136	-.230	-.052
	(.119)	(.107)	(.131)	(.079)
Constant	-.000***	.000***	-.000***	.000***
	(.000)	(.000)	(.000)	(.000)
Observations	320	580	340	600
R^2	.115	.062	.109	.046
Hansen J test, df=5	7.89	5.38	1.75	3.41
F_{instr}	4.84***	6.06***	5.27***	4.60***
F_{ξ^m}	4.50***	1.91	5.90***	2.20*
$F_{\xi^{w^s}}$	4.72***	9.26***	3.99***	6.36***

Note: * p<.1, ** p<.05, *** p<.01. Robust standard errors are in parenthesis. Variables are described in Table 2.5.2.1.

Considering the baseline specification (I), Table 2.6.0.2 shows that contemporaneous money demand shocks, are positively correlated with loan supply variation from 1999Q1 to 2008Q2, and are highly significant. Therefore, an exogenous increase to bank deposits increases the aggregate loan supply. This result confirms the findings in Rondorf (2012) that bank funds are imperfectly substitutable in the Euro-zone from 1999Q1 to the Lehman collapse. An increase in money demand shocks of one percentage point above the Euro-zone mean increases loans' growth by 0.093 percentage points above the Euro-zone average in the first quarter. This effect is not negligible, even if money demand shocks are small.

The coefficient on contemporaneous shocks to money demand have no statistically significant effect on loans once the crisis and subsequent periods are included in the estimation. Only the coefficient associated with the second lag is significant at the 95% confidence level. In contrast, the coefficients on contemporaneous shocks to bank debt issuance are positive and significant in all of the periods considered. In the baseline specification, before the financial turmoil, an increase in shocks to bank debt issuance of one percentage point in country i corresponds to an increase in the growth rate of real loans of 0.054 percentage points above the Euro-zone average. These estimates are 1.6 times larger in the estimation including the whole time frame. Moreover, they are more persistent. Indeed, there is a significant and positive effect of the first lag of bank debt shocks from 1999Q1 to 2014Q4. Thus, the results show that changes in bank preferences for long term debt were a significant driver of loan supply, and more so during the last financial turmoil. The findings suggest that the bank wholesale debt funding channel became important after the Lehman collapse for loan supply decisions. This supports the theory according to which wholesale fundings may have contributed to the severity of the crisis.

The Hansen J test of over-identifying restrictions shows that, at the 99% confidence level, at least some of the instruments are exogenous.

The estimation results in (II), in which the shocks are constructed without an instrumentation of output growth, confirm the results from the baseline specification. The coefficients associated with money demand are slightly larger and the ones corresponding to debt issuance shocks are slightly smaller. Additionally, Appendix 2.9.F shows that all the results are robust to the assumption on the bond rates. It also shows that, from 1999Q1 to 2014Q4, contemporaneous interest rates affect output significantly.

I now turn to the analysis of the strength of the instruments. Regarding the regression including the whole time frame, the joint F statistic in specification (II) is higher than in specification (I). The attempt to correct for endogeneity bias between output and money, and output and debt issuance gives estimates of financial shocks that have jointly more explanatory power on loan growth. On the contrary, before the crisis, the joint F test over all the excluded instruments is larger in specification (II), that is, without the instrumentation of output in the construction of the shocks. According to the "rule of thumb" (Stock and Yogo, 2005), to reject the null that the instrumental variable is weak, the F test on the joint restriction of coefficients associated with the instruments has to be larger than ten. In all of the specifications in Table 2.6.0.2, the F test is smaller than ten. However, before the Lehman collapse, the F test on the excluded debt shocks is close to 10 and, as shown in Appendix 2.9.F, becomes larger than 10 once heterogeneous bond rates enter the regression. Thus, in the baseline specification (I), we can reject the null hypothesis of irrelevance of the shock to debt issuance instruments $\xi_{i,t}^{w^s}$ before the crisis.

Consider now the second stage of the instrumentation. As displayed in Table 2.6.0.3, the baseline regression (I) shows that loan supply affects output positively and statistically, before and including the crisis. Before the Lehman collapse, the correlation of current loan growth with output growth is equal to 0.239 and is statistically significant. When the crisis and subsequent period are included in the regression, an increase in the growth of loan supply of one percentage point above the Euro-zone average in the country i yields to a significant increase in the growth rate of output of 0.599 percentage points above the Euro-zone mean. This is twice larger than before the crisis. Additionally, the second lag of loan growth is found to be negative and statistically different from zero in the long run.

It should be noted that the value of the estimated coefficients in the baseline regression (I) contrasts with specification (II), the regression in which financial shocks are constructed not taking into account potential endogeneity bias between output, debt issuance and money. In the regression (II), contemporaneous loan growth is not statistically significant. The coefficients associated with loan growth estimated over the whole period is 0.199, and it is equal to -0.007 before the crisis.

Hence, by attempting to confront endogeneity issues, the results point out that positive changes in loans that arise from a change in the preferences of banks for debt issuance and exogenous changes in deposits are significantly and positively associated with changes in output in the Euro-zone between 1999Q1 and 2014Q4. This result is driven by a strong positive relationship after the crisis of 2008.

The results on the significance, the sign, and the size of the coefficients in the baseline specification (I) are robust to the assumption on the heterogeneity of the bond rate over the whole sample. This can be verified in Appendix 2.9.F. However, before the crisis, the coefficient associated with contemporaneous loan growth is lower and no longer significant.

Table 2.6.0.3. – Second stage IV regression: Output on loans

OLS with FE	Dependent variable: $\Delta\tilde{y}_{i,t}$			
	Instrumentation		No instrumentation	
	(I)		(II)	
	(99Q1-08Q2)	(99Q1-14Q4)	(99Q1-08Q2)	(99Q1-14Q4)
$\Delta\hat{\tilde{l}}_{i,t}$	.239*	.599**	-.007	.199
	(.128)	(.222)	(.100)	(.195)
$\Delta\hat{\tilde{l}}_{i,t-1}$	.049	-.197	-.011	-.152
	(.095)	(.130)	(.100)	(.156)
$\Delta\hat{\tilde{l}}_{i,t-2}$	.080	-.192***	.114*	-.057
	(.092)	(.058)	(.059)	(.071)
$\Delta\tilde{y}_{i,t-1}$	-.389***	-.198**	-.343***	-.196**
	(.111)	(.071)	(.081)	(.068)
$\Delta\tilde{y}_{i,t-2}$	-.037	.071**	-.061*	.032
	(.045)	(.028)	(.029)	(.032)
Constant	-.000	.000***	-.000***	.000***
	(.000)	(.000)	(.000)	(.000)
Observations	300	560	320	580
log(likelihood)	1060.803	1960.706	1132.150	2015.189
R^2	.131	.115	.096	.046

Note: * p<.1, ** p<.05, *** p<.01. Robust standard errors are in parenthesis. Variables are described in Table 2.5.2.1.

The residual plot of the baseline regressions in the first and second stage, and Wilk test of normality are reported in Appendix 2.9.G. Residual plots do not reveal any non-linear functional pattern. Residuals are centered around zero and equally spaced around the zero mean. Their variability is larger than the predicted variable in both the first and second stage estimations. Although the residual plot does not suggest potential non-linearities, results from the linear estimation are driven by strong parametric assumptions. In contrast, non-parametric regressions let the data reveal the information on the distribution, instead of imposing one.

The Shapiro Wilk test of normality rejects the hypothesis of normally distributed data. The kernel estimate shows that the distribution kurtosis is too large relative to a standard normal distribution. While the OLS method does not produce a bias in the estimates when residuals are not normally distributed, the estimates are no longer efficient (the standard errors with OLS are no longer the smallest). Although robust standard errors can compensate for the standard errors, this potentially justifies the use of non-parametric regressions.

2.7. Investigation of non-linearities: non-parametric instrumental variables

The literature suggests that unstable bank liability items such as wholesale funds can raise uncertainty and systemic risk, and thus can be a source of non-linearities in economic fluctuations. In this section, the validity of the linear functional form is tested by estimating the two stage instrumental variable regression with non-parametric techniques.

Assuming a parametric form may lead to wrong conclusions. For example, parametric models give estimates that look more precise than they really are since the parametric estimates are based on the assumption that the parametric form is correct. The relevance of the parametric form imposed is particularly important in this study as the literature pointed out potential non-linearities in the relationship between bank funding shocks, loans and output. Specification testing does not eliminate the risk of misspecification of the model as a failure to reject a model does not imply that it is the correct one. Moreover, the parametric model assumes the model does not change with the sample size. Non-parametric models do not assume so. In particular, non-parametric techniques are data driven methods that feature the information available from the data, without imposing any functional forms.

There are very few applied studies using non-parametric instrumental variables (NPIV). Only recently has the econometric literature gained interest on NPIV techniques. Horowitz (2011) shows that NPIV can be estimated in the same way as in the linear estimation. The reduced form R^2 statistic provides information on the likelihood to find non-linearities in a non-parametric instrumental variable regression. Low R^2 are associated with large variance of non-linear coefficients (Newey, 2013). Therefore, the introduction of the second instrument increases the probability to find non-linearities, if they exist.

In this section, I use a class of model called Generalized Additive Models (GAM). This type of model allows covariates to non-linearly affect the dependent variable, while keeping the additivity between each regressor function in the regression. A major advantage of additive modeling is that it helps with the problem of "curse of dimensionality" that is associated with continuous random variables (i.e., the variance of the estimator increases with the dimension of the X). It can be shown that the statistical performance of the regression estimator decreases as the number of predictors in the kernel regression increases, i.e., the rate of convergence becomes slower (Haerdle, 1990). The specification is the following: $Y_{it} = \alpha + \Sigma_d m_d(X_{dit}) + e_{it}$, where $i = 1, ...n$ and $t = 1, ...T$. It is assumed that the covariates are exogenous ($E[e_{it} \mid X_{dit}] = 0$, for all d). The variables Y_{it} and X_{it} are a random sample, e_{it} are identically and independently distributed with mean zero and finite variance. Considering a uni-dimentional regression ($d = 1$), and exogenous X's,[26] the conditional expectation of Y on X, $E[Y_{it} \mid X_{it}]$, is just the function $m_d(X_{it})$. Since conditional expectations are functions of densities and conditional densities, it is possible to estimate this function using densities. Intuitively, the functions $m_d()$, called the regression functions, are estimated by dividing the sample X_d into small intervals, and fitting these small intervals using kernel density estimates as weights for the fit. The size of the interval, called the bandwidth, is crucial for the result of the estimation.[27] The cross validation method, standard in the non-parametric literature, is used to calculate the bandwidth.[28] The data is fitted with Gaussian kernels estimators with local linear regression. The backfitting algorithm then fits the additive components (the model) to the data. Therefore, the non-parametric model is:

$$\triangle \widetilde{l}_{it} = m_{\xi^{w^s}_{i,t}}(\xi^{w^s}_{i,t}) + m_{\xi^{m}_{i,t}}(\xi^{m}_{i,t}) + e_{1,it}, \tag{2.7.1}$$

$$\triangle \tilde{y}_{it} = m_{\widetilde{l}_{it}}(\triangle \widetilde{l}_{it}) + e_{2,it}, \tag{2.7.2}$$

[26] Severini and Tripathi (2012) relax the assumption of exogenous regressors but then the function $m()$ may not be uniquely defined.

[27] A bandwidth that is too small reduces the asymptotical bias of the estimator but increases the asymptotical variance. Inversely, a bandwidth that is too high reduces the variance but increases the bias.

[28] See Li and Racine (2007) p.83 for further details.

2.7.1. Non-parametric estimations

The literature points out potential non-linearities in the relationship between loans and output due to banks' large reliance on wholesale funding. Here, I analyze if a loan supply variation above or below the Euro-zone mean in country i, measured by country specific financial shocks, can affect output non-linearly. The non-linearities are country-specific and are in the sense that the response of output to small loan supply variations is distinguished from large variations. The non-parametric techniques allow to have different marginal effects at each point of the data. As in the linear regression, two lags of each variable are included in each of the regressions.

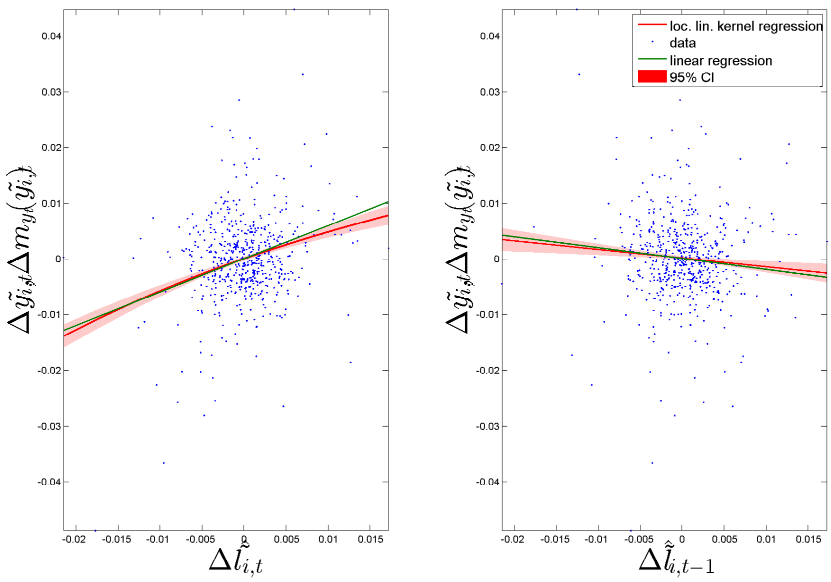
The non-parametric regressions of the first stage, before 2008Q2 and over the whole period, are displayed in Appendix 2.9.H. From 1999Q1 to 2008Q2, the marginal effects estimated with non-parametric techniques are larger than the linear estimate for positive variations of debt issuance shocks. Concerning negative values of debt issuance shocks, the confidence interval of the non-linear estimate does not incorporate the linear regression. The non-parametric prediction for negative variations of debt shocks is smaller than the linear prediction, and is not statistically significant, as it includes the zero line. The non-parametric prediction of the effect of money demand shocks on loans is larger at all data points except variations smaller than -0.05 percentage points below the Euro-zone mean.

Turning to the estimation over the whole time period, the first stage non-parametric prediction of the effect of financial shocks on loans matches the linear prediction. Money demand and debt issuance shocks have a positive and statistically significant effect on loan growth.

The data driven method second stage estimation before the Lehman collapse is in Appendix 2.9.H. It depicts a correlation between loans and output weaker than the one from the linear prediction.

Figure 2.7.1.1 displays the non-parametric and the linear estimations of output on current and lagged loans, over the whole time sample. Both linear and non-parametric techniques show a positive and significant correlation between loan supply and output. The non-parametric confidence interval includes the linear estimation except for variation of loans that are smaller than 0.01 percentage point above the Euro-zone mean. Thus, according to the non-linear estimates, the effect over this range of loan variation is weaker than

Figure 2.7.1.1. – Non-parametric estimation of the second stage (1999Q1-2014Q4)



Note: The variables $\widehat{\tilde{l}_{i,t}}$ is the predicted value from the non-linear first stage regression, as specified in the baseline regression.

predicted by the linear estimate. Finally, the non-linear estimate lagged loan variation matches the one predicted by the linear regression.

2.8. Conclusion

This study investigates how long term bank debt affects lending and the consequences for output. I estimate a linear two stage least square model with two instruments, shocks to money demand and shocks to bank long term debt issuance. Both shocks are constructed by estimating the money demand and bank debt issuance determinants with an error correction framework. In both estimations, output growth is instrumented. I find that both shocks are important determinants of loan supply in the Euro-zone between the first quarter of 1999 to the last quarter of 2014. Bank long term debt shocks have a particularly larger impact during and after the last financial turmoil. This confirms the suggestions found in the literature that disruptions on the wholesale market have larger impact on the economy during crises than in normal times. In addition, I find evidence that country specific variation in loan supply leads to country specific variation in output. The strength of the response is larger after the Lehman collapse. Finally, I test for the validity of the linearity assumption in the two stage least square estimation by using non-parametric instrumental variables. The results confirm the assumption about linearity of the functional form.

There are several extensions to this study. First, stronger instruments of output growth in the construction of bank debt issuance may help to better capture the relationship between bank debt issuance shocks, loan supply and output. Second, non-parametric instrumental variable methods, such as confidence intervals calculation, are still under explored and future research may contribute to the better detection of non-linearities. Third, one could measure changes in banking regulation and use it as an additional instrument. Fourth, the question of the existence of potential common non-linearities should also be investigated as the literature points towards possible threshold effects.

2.9. Appendices

2.9.A. Balance sheet composition

Tables 2.9.A.1 and 2.9.A.2 classify balance sheet items according the European Central Bank classification, and in increasing order of the coefficient of variation.

Table 2.9.A.1. – Banks Liabilities, shares (%) (1999Q1-2014Q4)

Variable	Mean %	Std	CV
Total Liabilities	100%	100	.998
Total deposits, excl. MFI	33.894	8.987	.265
(Domestic deposits, excl. MFI)	(31.801)	(9.032)	(.285)
Capital	6.603	2.08	.315
Total deposits, MFI	17.977	5.636	.315
Debt issuance (EU)	14.248	5.925	.416
(Domestic deposits, MFI)	(11.957)	(5.868)	(.491)
Debt issuance (non-EU)	9.392	5.416	.577
External liabilities	16.316	9.479	.581
MMF shares	1.569	2.09	1.332

Note: CV is the coefficient of variation. MMF shares include short term funds (with original maturity year) held by Euro area residents. External liabilities include non Euro area residents' holding of deposits and repurchase agreements, MMF shares and debt securities with maturity of less than or equal to 2 years. Debt issuance (non-EU) includes debt securities with maturity >2 years and held by non Euro area residents. It can be found under Remaining Liabilities in the ECB website. Debt securities (EU) are the ones held by Euro area residents with maturity >2 years. The data is taken from http://www.ecb.Europa.eu.

Table 2.9.A.2. – Banks Assets, shares (%) (1999Q1-2014Q4)

Variable	Mean %	Std	CV
Total loans, excl. MFI	41.071	10.6	.258
(Domestic loans, excl. MFI)	(39.279)	(11.271)	(.287)
Debt securities	14.02	4.625	.33
Total loans, MFI	16.318	5.676	.348
Equity held	3.714	1.679	.452
(Domestic loans, MFI)	(11.124)	(5.653)	(.508)
External Assets	15.645	9.259	.592
Remaining Assets	8.354	5.196	.622
Fixed Assets	.763	.636	.833
MMF shares	.117	.317	2.72

Note: CV is the coefficient of variation. MMF shares include short term assets (amounts issued by euro area residents). External Assets include holding of non Euro area residents of deposits, repurchase agreements, MMF shares and securities with maturitiy of less than or equal to 2 years. Remaining Assets are non Euro area residents securities with maturity >2 years. Debt securities are Euro area resident securities held with maturity >2 years. The data is taken from http://www.ecb.Europa.eu.

2.9.B. Stationarity tests

The Im-Pesaran-Shin panel unit root test verifies if all panels contain a unit root. Therefore, the null is rejected if only one or two countries series are stationary.

Since the test is only valid for serially uncorrelated error terms, I consider the serially uncorrelated error by assuming lags=0 and the test in which two lags of each variable are included in the test.[29] The results from the serially uncorrelated errors yield the same result as the test when I allow for serial correlation but control for it.

Table 2.9.B.1. – Im-Pesaran-Shin Panel unit-root test (1999Q1-2014Q4)

Null hypothesis: Unit root		
	lags=2	lags=0
variables	$\bar{W}$ statistic	$\bar{z}$ stat
$\tilde{W}_{i,t}$	1.12	1.47
$\tilde{m}_{i,t} - \tilde{p}_{i,t}$	.19	1.90
$\tilde{K}_{i,t}$	-.06	.09
$\tilde{y}_{i,t}$	2.4	1.99
$\tilde{A}_{i,t}$	.34	.43
$\tilde{r}_{i,t}$	-1.67**	1.12
$\tilde{l}_{i,t}$	1.32	.16
$\Delta\tilde{W}_{i,t}$	-6.17***	-10.90***
$\Delta(\tilde{m}_{i,t} - \tilde{p}_{i,t})$	-4.53***	-10.16***
$\Delta\tilde{K}_{i,t}$	-15.85***	-9.53***
$\Delta\tilde{y}_{i,t}$	-8.73***	-16.47***
$\Delta\tilde{A}_{i,t}$	-7.07***	-15.14***
$\Delta\tilde{r}_{i,t}$	-6.28***	-8.82***
$\Delta\tilde{l}_{i,t}$	-4.65***	-11.44***

Note: $*$,$**$,$***$ indicate significance at the 10%, 5%, 1% confidence level, respectively. The alternative is that some panel are stationary. Variables are described in Table 2.5.2.1.

[29] The command xtunitroot in stata assumes serially uncorrelated errors when no lags are specified.

2.9.C. Money demand shocks

Table 2.9.C.1. – First stage: Instrumentation of output growth in the money demand

OLS with FE	Dependent variable: $\Delta\tilde{y}_{i,t}$ (1999Q1-2008Q2)		(1999Q1-2014Q4)	
$\tilde{X}_{i,t}$	.031***	.029***	.020***	.020***
	(.008)	(.008)	(.004)	(.004)
$\Delta\tilde{y}_{i,t-1}$	-.403***	-.387***	-.241***	-.252***
	(.080)	(.080)	(.060)	(.060)
$\Delta(\tilde{m}_{i,t-1} - \tilde{p}_{i,t-1})$	.010	.013	.022	.024
	(.015)	(.016)	(.017)	(.017)
Error correction	-.008	-.007	-.006	-.012*
	(.010)	(.010)	(.006)	(.007)
$\tilde{y}_{i,t-1}$	-.034	-.048*	-.025*	-.044***
	(.021)	(.026)	(.013)	(.013)
$\Delta\tilde{r}_{i,t}$		.001		-.001*
		(.004)		(.000)
$\Delta\tilde{r}_{i,t-1}$		-.006		.000
		(.005)		(.000)
$\tilde{r}_{i,t-1}$		-.004		-.000***
		(.003)		(.000)
Observations	360	360	620	620
R^2	.067	.099	.058	.066
KPW $F_{1,\#obs-15(-3)}$	13.03***	14.62***	20.30***	20.45***

Note: * p<.1, ** p<.05, *** p<.01. Robust standard errors are in parenthesis. The statistic KPW $F_{d,\#obs-15(-3)}$ is the Kleibergen-Paap Wald rk F statistic where d is the degrees of freedom, to be compared to the Stock and Yogo critical values. The variable $\tilde{X}_{i,t}$ is log of total exports per capita and deflated, centered around its cross-sectional mean. Other variables are described in Table 2.5.2.1.

Table 2.9.C.2. – Money demand

Dynamic fixed effects	Dependent variable: $\Delta(\tilde{m}_{i,t} - \tilde{p}_{i,t})$							
	Second stage (I)				No instrumentation (II)			
	(1999Q1-2008Q2)		(1999Q1-2014Q4)		(1999Q1-2008Q2)		(1999Q1-2014Q4)	
Error correction	-.083***	-.081***	-.098***	-.108***	-.081***	-.080***	-.096**	-.105***
	(.030)	(.029)	(.026)	(.029)	(.013)	(.013)	(.031)	(.029)
$\tilde{y}_{i,t-1}$	.131**	.106	.138***	.104**	.173***	.147*	.147***	.119***
	(.058)	(.077)	(.045)	(.043)	(.029)	(.078)	(.039)	(.034)
$\tilde{r}_{i,t-1}$		-.012		-.001*		-.010		-.001***
		(.012)		(.000)		(.018)		(.000)
$\Delta\tilde{y}_{i,t}$	.129	.219	-.044	-.047	.687***	.664***	.309***	.272***
	(.524)	(.528)	(.630)	(.628)	(.132)	(.089)	(.072)	(.070)
$\Delta\tilde{y}_{i,t-1}$	.297	.360	-.025	-.040	.468*	.490*	.045	.026
	(.270)	(.253)	(.224)	(.227)	(.229)	(.249)	(.100)	(.117)
$\Delta\tilde{r}_{i,t}$		.029		-.001		.030**		-.001
		(.020)		(.001)		(.013)		(.002)
$\Delta\tilde{r}_{i,t-1}$		-.001		.002		.003		.002**
		(.014)		(.001)		(.016)		(.001)
$\Delta(\tilde{m}_{i,t-1} - \tilde{p}_{i,t-1})$	-.011	-.014	.070	.074	-.015	-.019	.062	.067
	(.069)	(.067)	(.063)	(.064)	(.046)	(.048)	(.048)	(.046)
Constant					.000**	.000*	.000***	.000***
					(.000)	(.000)	(.000)	(.000)
Observations	360	360	620	620	360	360	620	620
R^2	.067	.099	.059	.067	.094	.116	.071	.076

Note: * p<.1, ** p<.05, *** p<.01. Robust standard errors are in parenthesis. Variables are described in Table 2.5.2.1.

2.9.D. Debt issuance determinants: comparison with Rixtel et al. (2015)

Table 2.9.D.1. – Rixtel et al. (2015)' country specific results versus my estimation, before crisis

	(A)		(B)
Dep. variable	$\log(\text{Total Issuance}_{i,t})$ aggregate bank level	Dep. variable	$\log(\text{Total Issuance}_{i,t})$ FE country level
variables	(1999Q1-2007Q3)	variables	(1999Q1-2007Q3)
term spread$_{j,t}$	-.15*	$\tilde{r}_{i,t}$	.03
	(.08)		(.30)
	-.13**		
	(.06)		
bank stock$_{j,t}$	2.06**		
	(.92)		
$\frac{\triangle A_{i,t}}{A_{i,t-1}}$	6.68***	$\frac{\triangle \tilde{A}_{i,t}}{A_{i,t}}$	-.62
	(2.05)		(.89)
$\frac{K}{A}{i,t}$	12.45**	$\tilde{\frac{K}{A}}{i,t}$	-4.39
	(6.18)		(7.13)
$A_{i,t}$	2.01***	$\tilde{A_{i,t}}$	2.04***
	(.442)		(.47)
$\frac{\triangle y_{i,t}}{y_{i,t-1}}$	.01	$\frac{\triangle \tilde{y}_{i,t}}{y_{i,t-1}}$	-.69
	(.03)		(.72)
$Libor - OIS_t$	-.01**	$Libor - OIS_t$	
	(.01)		
Vol_t	-.02***	Vol_t	
	(.01)		
constant	-15.32***	constant	1.99**
	(5.90)		(.47)
Observations	1120	Observations	340
R^2	.72	R^2	.55
dummies	country and year	dummies	country

Note: $*$,$**$,$***$ indicate significance at the 10%, 5%, 1% confidence level, respectively; robust standard errors are in parenthesis. Specification (A) corresponds to the results from Rixtel et al., 2015 study. The dependent variable is log of the total amount of bonds issued by banks headquartered in country i and the data is monthly. In my estimation (B), variables denoted with a tilde are centered variable as described in Table 2.5.2.1. The variable term spread$_{j,t}$ corresponds to the 10 year government bond yield minus the 3 month government bill rate for country i. The variable Vol_t measures Implied Stock market volatility (VSTOXX). The variable bank stock$_{j,t}$ is the stock market index of the banking sector in country i.

Table 2.9.D.3. – Summary statistics (2005Q1-2007Q3)

	(1) Country variables				(2) Bank variables (Rixtel et al., 2015)			
	(2005Q1-2013Q1)				(2005Q1-2013Q1)			
variables	mean	std	min	max	mean	std	min	max
Total Assets (millions)	2806463	2569706	228472.3	8651474	489999	543572	5545	2586700
$\frac{K}{A}_{i,t-1}$	0.06	0.02	0.03	0.12	0.04	0.02	0	0.15
$\frac{D}{A}_{i,t-1}$	0.33	0.09	0.12	0.52	0.32	0.14	0	0.82
$\frac{L}{A}_{i,t-1}$	0.38	0.12	0.10	0.61	0.49	0.16	0.08	0.98
$r_{i,t}$	0.13	0.05	0.04	0.45	0.036	0.018	0.005	0.36
$\frac{\triangle y_{i,t}}{y_{i,t-1}}$	0	0.01	-0.05	0.03	0.01	0.028	-0.09	0.082
$\frac{W}{A}_{i,t-1}$	0.15	0.06	0.05	0.25	0.011	0.016	0	0.189

Note: Variables are quarterly data. The data in the country level regressions are seasonally adjusted.

2.9.E. Debt issuance shocks

Table 2.9.E.1. – First stage: Instrumentation of output growth in debt issuance

Ordinary least squares with FE	Dependent variable: $\Delta\tilde{y}_{i,t}$ 1999Q1-2008Q2		1999Q1-2014Q4	
$\Delta\tilde{y}_{i,t-2}$	-.196*	-.190*	-.077	-.090
	(.108)	(.101)	(.059)	(.060)
$\Delta g\tilde{a}p_{i,t-3}$	-.021	-.024	-.045**	-.046**
	(.035)	(.035)	(.022)	(.022)
$\Delta g\tilde{a}p_{i,t}$	-.029	-.028	-.056***	-.060***
	(.027)	(.026)	(.019)	(.019)
$\tilde{X}_{i,t-1}$	.006	.007	-.021**	-.020*
	(.012)	(.012)	(.011)	(.011)
$\tilde{X}_{i,t}$	.032***	.031***	.035***	.036***
	(.012)	(.012)	(.011)	(.011)
$\Delta\tilde{y}_{i,t-1}$	-.530***	-.517***	-.315***	-.328***
	(.095)	(.088)	(.058)	(.059)
$\Delta\tilde{A}_{i,t}$a	.027	.025	.038**	.035**
	(.023)	(.023)	(.015)	(.015)
$\Delta\tilde{A}_{i,t-1}$	.044*	.045*	.015	.011
	(.025)	(.024)	(.019)	(.019)
$\Delta\tilde{K}_{i,t}$	-.017**	-.016**	-.018***	-.016**
	(.007)	(.007)	(.006)	(.006)
$\Delta\tilde{K}_{i,t-1}$	-.010	-.010	.001	-.000
	(.008)	(.008)	(.006)	(.006)
$\Delta(\tilde{m}_{i,t} - \tilde{p}_{i,t})$	.058***	.057***	.042**	.039*
	(.019)	(.018)	(.021)	(.022)
$\Delta(\tilde{m}_{i,t-1} - \tilde{p}_{i,t-1})$	.010	.016	.012	.016
	(.014)	(.015)	(.013)	(.014)
$\Delta\tilde{r}_{i,t}$		.001		-.001*
		(.004)		(.000)
$\Delta\tilde{r}_{i,t-1}$		-.008		.000
		(.005)		(.000)
$\Delta\tilde{W}_{i,t-1}$	.003	.001	.009	.008
	(.011)	(.011)	(.009)	(.009)
$\tilde{W}_{i,t-1}$	.001	.001	-.003*	-.001
	(.002)	(.002)	(.001)	(.001)
$\tilde{m}_{i,t-1} - \tilde{p}_{i,t-1}$	-.006	-.006	.002	-.004
	(.012)	(.012)	(.008)	(.009)
$\tilde{A}_{i,t-1}$	.001	.002	-.007	-.007
	(.011)	(.011)	(.005)	(.005)
$\tilde{K}_{i,t-1}$	-.000	-.000	.000	.001
	(.004)	(.004)	(.003)	(.003)
$\tilde{y}_{i,t-1}$	-.035	-.041	-.017	-.028**
	(.034)	(.034)	(.013)	(.013)
$\tilde{r}_{i,t-1}$		.000		-.000***
		(.003)		(.000)
Observations	340	340	600	600
R^2	.33	.35	.32	.33
KPW $F_{5,\#obs-28(-3)}$	3.03**	3.16***	5.52***	5.90***
Hansen J test	2.29	2.68	5.74	5.55

Note: * p<.1, ** p<.05, *** p<.01. Robust standard errors are in parenthesis. The statistic KPW $F_{d,\#obs-28(-3)}$ is the Kleibergen-Paap Wald rk F statistic where d is the degrees of freedom, to be compared to the Stock and Yogo critical values. Variables are described in Table 2.5.2.1.

Table 2.9.E.2. – Debt determinants (1999Q1-2008Q2)

Dynamic Fixed Effects	Dependent variable: $\Delta \tilde{W}_{i,t}$ second stage (I)		no instrumentation (II)	
Error correction	-.032***	-.033***	-.027**	-.027**
	(.011)	(.011)	(.009)	(.010)
$(\tilde{m}_{i,t-1} - \tilde{p}_{i,t-1})$	-.190***	-.198***	-.156**	-.161**
	(.048)	(.046)	(.060)	(.058)
$\tilde{A}_{i,t-1}$	.107*	.125**	.084*	.090
	(.063)	(.062)	(.044)	(.054)
$\tilde{K}_{i,t-1}$	.017	.018	.002	.003
	(.021)	(.020)	(.014)	(.015)
$\tilde{y}_{i,t-1}$	.242	.293	.080	.131
	(.168)	(.187)	(.238)	(.262)
$\tilde{r}_{i,t-1}$		.026		.023
		(.018)		(.039)
$\Delta\tilde{y}_{i,t}$	.635	.824	.564***	.628**
	(1.113)	(1.090)	(.172)	(.213)
$\Delta\tilde{y}_{i,t-1}$	.498	.504	.403	.354
	(.622)	(.600)	(.321)	(.316)
$\Delta\tilde{A}_{i,t}$	.483***	.507***	.466***	.474***
	(.135)	(.124)	(.137)	(.122)
$\Delta\tilde{A}_{i,t-1}$	-.089	-.092	-.093	-.090
	(.133)	(.133)	(.160)	(.155)
$\Delta(\tilde{m}_{i,t} - \tilde{p}_{i,t})$	.005	.037	.047	.080
	(.189)	(.178)	(.099)	(.090)
$\Delta(\tilde{m}_{i,t-1} - \tilde{p}_{i,t-1})$	-.396***	-.395***	-.383***	-.381***
	(.084)	(.077)	(.086)	(.084)
$\Delta\tilde{K}_{i,t}$	-.043	-.032	-.081	-.075
	(.068)	(.064)	(.060)	(.060)
$\Delta\tilde{K}_{i,t-1}$	-.039	-.045	-.038	-.039
	(.058)	(.059)	(.084)	(.083)
$\Delta\tilde{r}_{i,t}$		-.046*		-.032
		(.024)		(.038)
$\Delta\tilde{r}_{i,t-1}$		.009		.009
		(.033)		(.029)
$\Delta\tilde{W}_{i,t-1}$	.325***	.320***	.347***	.341***
	(.062)	(.059)	(.067)	(.053)
Constant			.000	.000
			(.000)	(.000)
Observations	340	340	360	360
log(likelihood)	640.474	645.940	671.322	674.807
R^2	.325	.347	.297	.311

Note: * p<.1, ** p<.05, *** p<.01. Robust standard errors are in parenthesis. Variables are described in Table 2.5.2.1.

2.9.F. Robustness checks: bond rate heterogeneity

Table 2.9.F.1. – First stage IV regression: Loans on financial shocks, with heterogeneous bond rates across countries

OLS with FE	Dependent variable: $\Delta\tilde{l}_{i,t}$			
	Instrumentation (y) (I)		No instrumentation (II)	
	(99Q1-08Q2)	(99Q1-14Q4)	(99Q1-08Q2)	(99Q1-14Q4)
${\xi^m}_{i,t}$	.099***	.027	.114***	.032
	(.024)	(.027)	(.027)	(.028)
${\xi^m}_{i,t-1}$	-.047*	.003	-.044	.007
	(.025)	(.020)	(.028)	(.019)
${\xi^m}_{i,t-2}$	-.005	.051**	-.008	.058**
	(.021)	(.021)	(.022)	(.024)
${\xi^{w^s}}_{i,t}$	.050**	.091**	.045***	.072**
	(.016)	(.037)	(.010)	(.022)
${\xi^{w^s}}_{i,t-1}$	.029	.040*	.035	.042*
	(.025)	(.019)	(.022)	(.020)
${\xi^{w^s}}_{i,t-2}$	.030	.032	.025	.032
	(.018)	(.029)	(.030)	(.034)
$\Delta\tilde{y}_{i,t-1}$	-.026	-.015	.004	.042
	(.100)	(.054)	(.124)	(.037)
$\Delta\tilde{y}_{i,t-2}$	-.301**	-.105	-.246*	-.025
	(.111)	(.102)	(.122)	(.074)
$\Delta\tilde{r}_{i,t}$	-.009	.002**	-.002	.002**
	(.006)	(.001)	(.003)	(.001)
$\Delta\tilde{r}_{i,t-1}$	-.005	-.000	-.008	-.000
	(.005)	(.000)	(.006)	(.000)
$\Delta\tilde{r}_{i,t-2}$	.004	-.001**	.010	-.001
	(.004)	(.000)	(.007)	(.000)
Constant	-.000***	.000***	-.000***	.000***
	(.000)	(.000)	(.000)	(.000)
Observations	320	580	340	600
R^2	.123	.074	.118	.059
Hansen J test, df=5	8.68	4.00	1.75	2.16
F_{instr}	4.84***	6.12***	5.17***	4.75***
F_{ξ^m}	4.76***	1.30	5.72***	1.71
$F_{\xi^{w^s}}$	4.50***	10.21***	3.99***	7.24 ***

Note: * p<.1, ** p<.05, *** p<.01. Robust standard errors are in parenthesis. Variables are described in Table 2.5.2.1.

Table 2.9.F.2. – Second stage IV regression: Output on loans, with heterogeneous bond rates across countries

OLS with FE	Dependent variable: $\Delta\tilde{y}_{i,t}$			
	Instrumentation (y) (I)		No instrumentation (II)	
	(99Q1-08Q2)	(99Q1-14Q4)	(99Q1-08Q2)	(99Q1-14Q4)
$\Delta\hat{\tilde{l}}_{i,t}$	.141	.541**	-.045	.136
	(.107)	(.228)	(.086)	(.179)
$\Delta\hat{\tilde{l}}_{i,t-1}$	.095	-.143	.041	-.092
	(.104)	(.139)	(.094)	(.163)
$\Delta\hat{\tilde{l}}_{i,t-2}$	.121	-.104*	.121	.026
	(.110)	(.050)	(.076)	(.052)
$\Delta\tilde{y}_{i,t-1}$	-.374***	-.221**	-.322***	-.204**
	(.078)	(.073)	(.053)	(.069)
$\Delta\tilde{y}_{i,t-2}$	-.062	.039	-.066**	.019
	(.044)	(.033)	(.029)	(.034)
$\Delta\tilde{r}_{i,t}$	.004	-.001*	.003	-.001
	(.009)	(.001)	(.008)	(.001)
$\Delta\tilde{r}_{i,t-1}$	-.013	.001	-.015	.000
	(.010)	(.001)	(.011)	(.001)
$\Delta\tilde{r}_{i,t-2}$	.004	.000	.004	-.000
	(.004)	(.000)	(.003)	(.000)
Constant	-.000	.000***	-.000***	.000***
	(.000)	(.000)	(.000)	(.000)
Observations	300	560	320	580
log(likelihood)	1065.997	1958.282	1138.899	2015.385
R^2	.161	.108	.134	.047

Note: * p<.1, ** p<.05, *** p<.01. Robust standard errors are in parenthesis. Variables are described in Table 2.5.2.1.

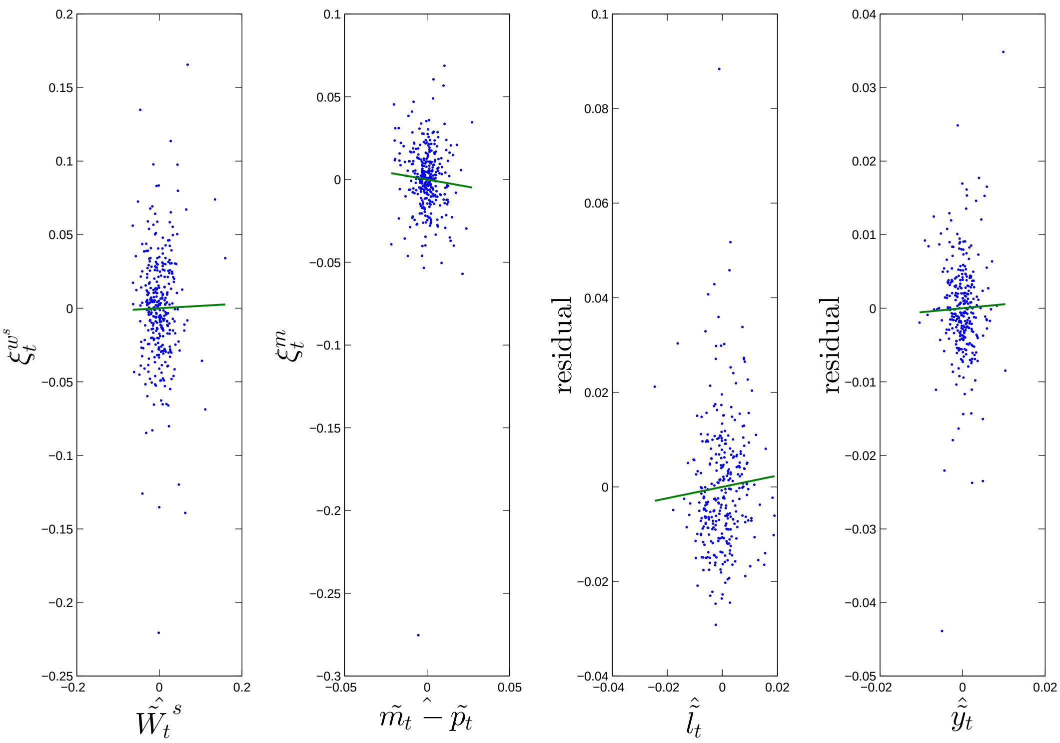
2.9.G. Residual analysis

Table 2.9.G.1. – Shapiro-Wilk Test of Normality

assumption on bond rates:	r_t		$r_{i,t}$	
Time period	Stage 1	Stage 2	Stage 1	Stage 2
1999Q1-2008Q2	.943***	.921***	.927***	.904***
1999Q1-2014Q4	.927***	.922***	.941***	.927***

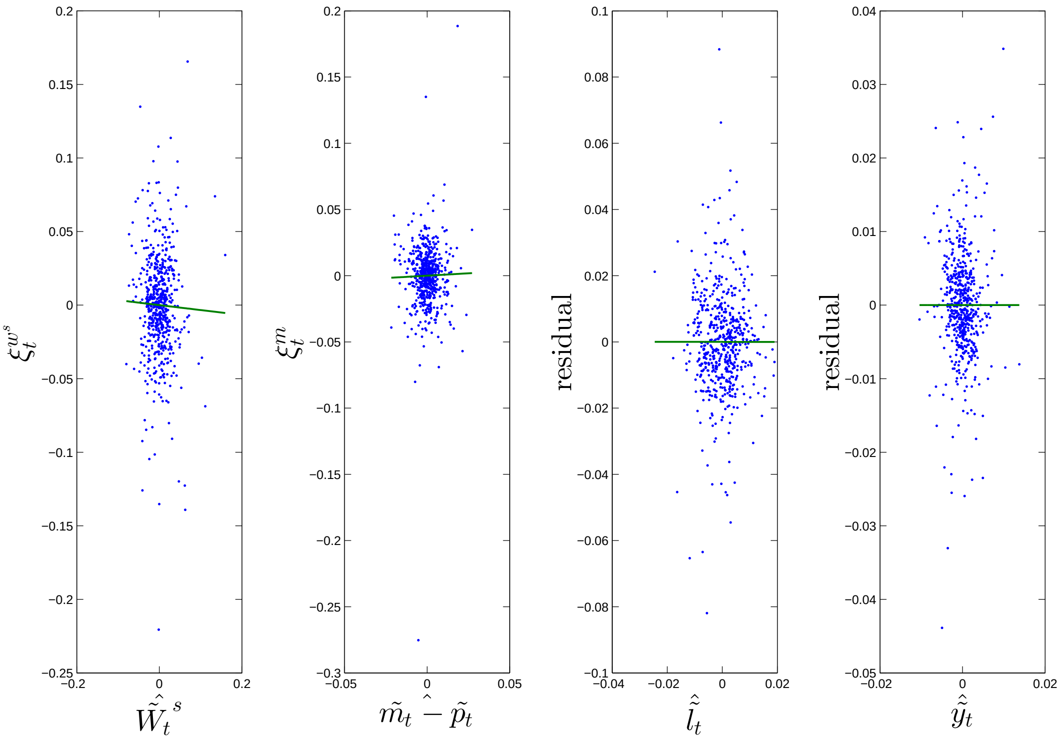
Note: * p<.1, ** p<.05, *** p<.01. The baseline specification (I) is considered. The null hypothesis (H0) is: residuals are normally distributed. Variables are described in Table 2.5.2.1. The specification (r_t) are the 2SLS estimations when the bond rate is considered the same across countries. The regression $r_{i,t}$ is when a heterogeneous bond rate is used.

Figure 2.9.G.1. – Residual plot (1999Q1-2008Q2)



Note: The graph plots the residual against the predicted values in the baseline specification (I) with equal bond rates across countries. Variables are described in Table 2.5.2.1.

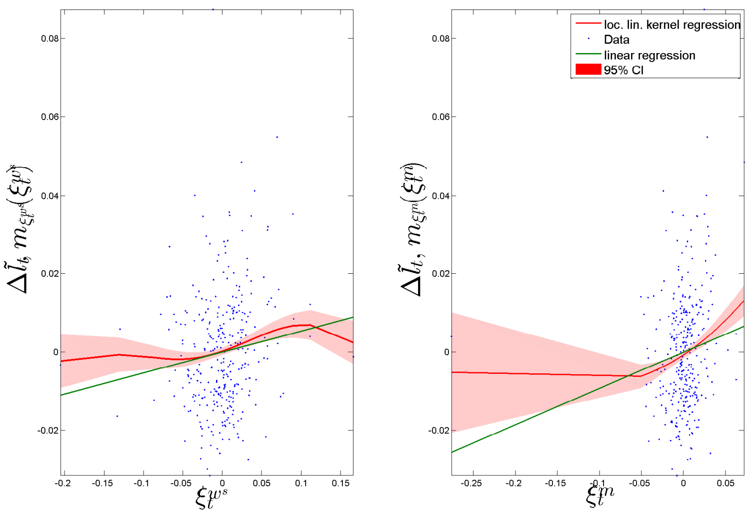
Figure 2.9.G.2. – Residual plot (1999Q1-2014Q4)



Note: The graph plots the residual against the predicted values in the baseline specification (I) with equal bond rates across countries. Variables are described in Table 2.5.2.1.

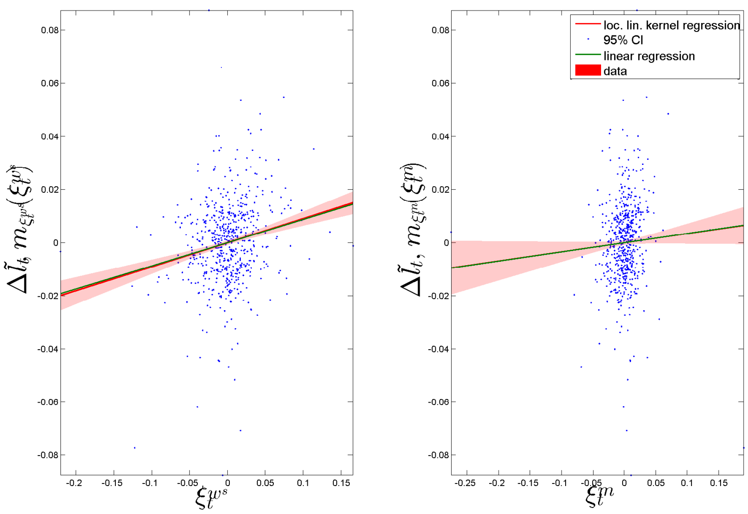
2.9.H. Non-parametric estimations

Figure 2.9.H.1. – Non-parametric estimation of the first stage (1999Q1-2008Q2)



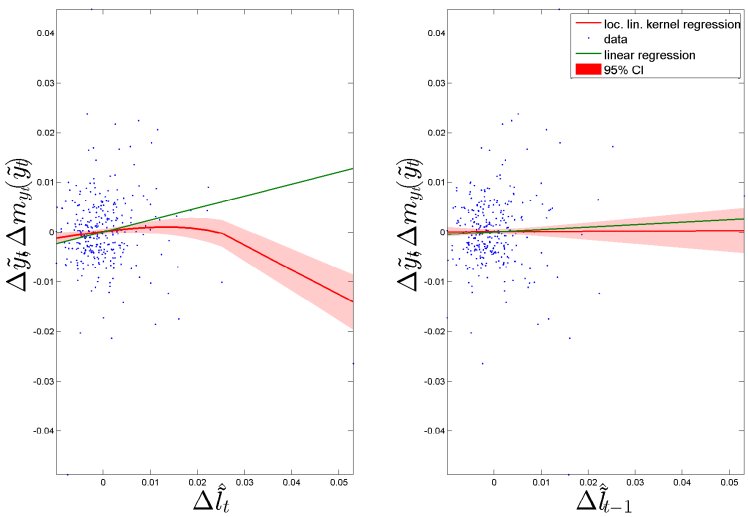
Note: The variables ξ_t^m and $\xi_t^{w^s}$ are, respectively, shocks to money demand and shocks to debt issuance as computed in the baseline specification.

Figure 2.9.H.2. – Non-parametric estimation of the first stage (1999Q1-2014Q4)



Note: The variables ξ_t^m and $\xi_t^{w^s}$ are, respectively, shocks to money demand and shocks to debt issuance as computed in the baseline specification.

Figure 2.9.H.3. – Non-parametric estimation of the second stage (1999Q1-2008Q2)



Note: The variables $\hat{\tilde{l}}_{i,t}$ is the predicted value from the non-linear first stage regression, as specified in the baseline regression.

3. Regulation and Rational Banking Bubbles in Infinite Horizon[1]

3.1. Introduction

The Great Recession of 2007-2009 has highlighted the importance of the banking sector in the worldwide economy and its role in the propagation of the crisis. Valuation and liquidity problems in the U.S. banking system are recognized to be a cause of the crisis (Miao and Wang, 2015). In particular, Miao and Wang (2015) argue that changes in agents' beliefs about stock market value of banks are suspected to explain sudden financial market crashes.

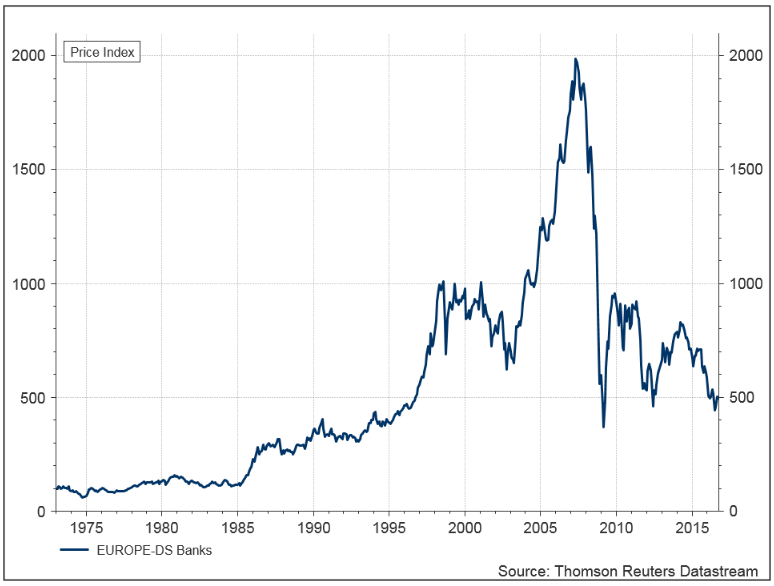
As a consequence, there has been a greater awareness among both academics and policy makers about the failure of banking regulation in preventing crises. The Basel committee on Banking Supervision was created in 1973 "to enhance understanding of key supervisory issues and improve the quality of banking supervision worldwide".[2] They released the first Basel Accord, called "Basel I" in 1988. The goal of Basel I was to create a framework for internationally active banks, in particular seeking, to prevent international banks from growing without adequate capital. Therefore, the committee imposed minimum capital requirements which were calculated based on credit risk weights of loans. Credit risk weights take into account possible losses on the asset side of a bank's balance sheet. The idea was that banks holding riskier assets had to hold more capital than other banks in order to ensure solvency. This approach has been criticized by researchers and regulatory agencies because it only considers

[1]This chapter is based on Chevallier and El Joueidi (2016)

[2]For more details, see The Basel Committee overview, https://www.bis.org/bcbs/.

credit risk and does not encompass market risk.[3] Market risk refers to the risk of losses from changes in market prices, which increases banks' default risk. The Basel committee has recognized this problem and released the Basel II Capital Accord.[4] This new accord also considers market values into the banking regulation framework in order to take into account market risk of the trading book. It allows banks to use an internal model based on *Value-at-Risk* to quantify their minimum capital requirements. The idea of capital requirements based on Value-at-Risk is to impose a solvency condition for banks which requires that the maximum amount of debt that banks can hold, do not exceed the market value of banks assets in the worst case scenario.[5]

Figure 3.1.0.1. – Banks stock price index



The aim of this study is to analyze the impact of banking regulation and in particular, Basel II, on the development of *stochastic bubbles* on banks' stock prices. A stochastic bubble on a bank's stock price is defined as a temporary deviation of the bank's stock price from the bank's fundamental value. Figure

[3]For example, Dimson and Marsh (1995) analyze the relationship between economic risk and capital requirements using trading book positions of UK securities firms. They find that the Basel I approach leads only to modest correlation between capital requirements and total risk.

[4]See Basel Committee on Banking Supervision (2004).

[5]Basel III, released in 2011, also proposes to use the Value-at-Risk to measure the minimum capital requirement. The difference with Basel II is that it is amended to include a Stressed-Value-at-Risk (SVaR). It aims at reducing pro-cyclicality of the market risk approach and insures that banks hold enough capital to survive long periods of stress.

3.1.0.1 plots the price index of 168 banks listed in Europe from 1973 to 2016. It shows that the price index has sharply increased from 2004, which coincides with the release of Basel II. Therefore, we suspect that the Basel II regulatory framework has allowed the existence of bubbles in the banking sector.

This chapter also focuses on the effect of bubbles on macroeconomic key variables. Following Blanchard and Watson (1982) and Weil (1987), stochastic bubbles are bubbles that have an exogenous constant probability of bursting. Once they burst, they do not reemerge. We develop a dynamic stochastic general equilibrium model with three types of infinitely lived agents, banks, households, and firms, as well as a regulatory authority. Banks raise funds by accumulating net worth and demanding deposits (supplied by households) to provide loans to firms. Firms produce the consumption goods, invest and are subject to productivity shocks. The regulatory authority imposes two banking regulations. The first requires that banks keep a fraction of deposits as reserves. These reserves cannot be used to invest in loans (risky assets). The second measure requires banks to have an upper limit on the quantity of deposits based on Value-at-Risk capital requirements.

We show that bubbles emerge if agents believe that they exist. Thus, expectations of agents are self-fulfilling. Results suggest that when banks face capital requirements based on Value-at-Risk, two different equilibria emerge and can exist: the bubbleless and the stochastic bubbly equilibria. Capital requirements based on Value-at-Risk allow bubbles to exist. In contrast, under a regulatory framework where capital requirements are based on credit risk only, as in Basel I, banking bubbles are explosive and as a consequence cannot exist. The stochastic bubbly equilibrium before the bubble bursts is characterized by positive or negative bubbles depending on the tightness of capital requirements. A positive (resp. negative) bubble is a "persistent" overvaluation (resp. undervaluation) of the banking stock price. We find a maximum value of the capital requirement based on Value-at-Risk under which bubbles are positive. Below this value and until the bubble bursts, the stochastic bubbly equilibrium provides larger welfare than the bubbleless equilibrium. The intuition is that, when agents consider that a bubble exists, lower capital requirements lead to optimistic beliefs about bank valuation. Bubbles allow banks to relax the capital requirement constraint, and thus banks demand more deposits and make more loans. This effect reduces the lending rate and provides higher welfare. Profits of banks rise which increases the value of banks. As a consequence, initial beliefs about the value of banks are realized. In contrast, above this maximum capital requirement, bubbles are negative leading to a credit crunch and thus, reduce welfare. Therefore, our model shows that a change in regulation might lead to a crisis, by shifting the economy from higher to lower welfare. This can explain the existence of crises without external shocks. We also show that the equilibrium with positive stochastic bubbles exists if the probability that bubbles collapse is small. This is consistent with Weil (1987) and Miao and Wang (2015). Moreover, as in Miao and Wang (2015), our results suggest that after the bubble bursts, consumption, welfare, and output fall. Consequently, a change in beliefs also modifies the equilibrium, from higher to lower welfare. Finally, we simulate impulse response functions to a negative productivity shock. The results show that bubbles do not amplify the effect of a negative productivity shock on the economy.

This study is related to two strands of literature. First, it is related to the literature on banking regulation. Indeed, there is a very recent move towards macroeconomic models incorporating a banking sector (de Walque et al., 2010; Gertler and Kiyotaki, 2011; Gertler and Karadi, 2011; Gertler et al., 2012; He and Krishnamurthy, 2012; Brunnermeier and Sannikov, 2014). In particular, we focus on banking regulation and their impact on macroeconomic variables as in Dib (2010) and de Walque et al. (2010). As in Dangl and Lehar (2004) and Tomura et al. (2014), we study the impact of Value-at-Risk banking regulation on the economy. Dangl and Lehar (2004) compare the effect of capital regulation based on Basel I and Value-at-Risk internal model approach. They find that the latter regulation reduces risk in the economy. Tomura et al. (2014) introduce asset illiquidity in a dynamic stochastic general equilibrium model and show that capital requirements based on Value-at-Risk can lead banks to adopt macro-prudential behavior. We contribute to this literature by showing that capital requirements based on Value-at-Risk allow bubbles to exist. In contrast, under a regulatory framework where capital requirements are based on credit risk only, as in Basel I, bubbles are explosive and as a consequence cannot exist.

Second, this study is related to the literature on the existence and the effect of rational bubbles in infinite horizon and, in particular, on stochastic bubbles. The literature on the existence of bubbles in general equilibrium models with infinitely lived agents is scarce and marked with few important contributions (Miao, 2014). Therefore, the understanding of financial bubbles in infinite horizon models is still under explored. Tirole (1982) shows that bubbles under rational expectations with infinitely lived agents cannot exist. In addition, Blanchard and Watson (1982) argue that "the only reason to hold an asset whose price is above its fundamental value is to resell it at some time and to realize the expected capital gain. But if all agents intend to sell in finite time, nobody will be holding the asset thereafter, and this cannot be an equilibrium". Such behavior implies that agents over save so that they do not consume everything they could. This cannot be an equilibrium since agents would deviate to increase their consumption levels and, thus, the so called *transversality condition* (TVC) is not satisfied. In contrast, Kocherlakota (1992) demonstrates that bubbles may exist in an infinite horizon general equilibrium model with borrowing or wealth constraints. These constraints limit the agent arbitrage opportunities by introducing some portfolio constraints. Foremost, Kocherlakota (2008) shows that equilibrium in which the asset price contains a bubble can exist with the bubbleless equilibrium in the presence of debt constraints. The only difference between the two states (bubbles and no bubbles) is that the bubbly one modifies the debt limit. The author calls this result the "bubble equivalence theorem". We contribute to this literature by showing that banking bubbles may emerge with banking regulation based on Value-at-Risk in an infinite horizon general equilibrium framework.

Our study is mostly related to Miao and Wang (2015). They insert an endogenous borrowing constraint and show that bubbles can emerge in an infinitely lived general equilibrium framework without uncertainty. Bubbles are introduced through the bank problem. We borrow the same methodology to introduce bubbles. Nevertheless, our model contrasts with Miao and Wang (2015) regarding four major characteristics. First, our key idea is to introduce banking regulation in an infinitely lived agent model to analyze whether stochastic bubbles can arise. Second, our model is a stochastic general equilibrium. In contrast, Miao and Wang (2015) consider a deterministic model. Third, negative bubbles as well as positive bubbles can arise, while they only assume positive bubbles. Fourth, they consider an agency problem to justify a minimum dividend policy that links dividends to net worth. Our model does not impose a dividend policy.

The present chapter is organized as follows. Section 3.2 presents the model. Section 3.3 and section 3.4 analyze, respectively, the bubbleless and the stochastic bubbly general equilibrium. Section 3.5 compares both equilibria. Section 3.6 presents the calibration, explores local dynamics and compares impulse response functions to a negative productivity shock for both equilibria. Finally, the last section concludes.

3.2. Model

We consider an economy with three types of infinitely lived agents, banks, households, and firms, as well as a regulatory authority. In this model, banking bubbles can arise. They emerge only if agents believe that banks' stock prices contain a bubble. The bubble is, thus, self-fulfilling. Banks, households, and firms are respectively represented by a continuum of identical agents of mass one. Households are shareholders of banks and owners of firms. It is assumed that banks have the necessary technology and knowledge to engage in lending activity while households do not. Thus, the latter do not lend directly to non-financial firms and have recourse to banks. At the end of each period, banks raise funds internally, using net worth, and externally, by taking deposits from households. Using raised funds, they lend to firms which produce consumption goods. In the model, a bubble is introduced through the bank problem, as in Miao and Wang (2015). We consider a bubble with an exogenous probability of burst, i.e., a *stochastic bubble* as in Blanchard and Watson (1982). Although a bubble can only arise if agents believe in its existence, it is not an agent choice. Agents are "bubble takers". The optimization problem of each agent is presented in this section.

3.2.1. Households

Households are represented by a continuum of identical agents of unit mass. Each household starts with an initial endowment of stocks s_0 and deposits D_0. At each period t, it receives net profits π_t generated by firms, it chooses its optimal consumption c_t, amount of stocks s_{t+1}, and deposits D_{t+1} for the next period. It also receives dividends d_t from the shares s_t it owns, sells its shares at price p_{t+1} and obtains an interest rate r_t on the amount deposited D_t in the previous period. There is no uncertainty on savings and thus r_t is the risk-free interest rate. We assume that preferences of households are represented by a linear utility function in consumption. Given their budget constraint (3.2.1), each household chooses the optimal amount of shares, deposits and consumption $\{s_{t+1}, D_{t+1}, c_t\}_{t=0}^{\infty}$ that maximizes its expected lifetime linear utility. Each household optimization problem is defined as follows:

$$Max_{\{s_{t+1},D_{t+1},c_t\}_{t=0}^{\infty}} E_t \sum_{t=0}^{\infty} \beta^t c_t,$$

subject to

$$D_t\left(1+r_t\right)+s_t\left(p_{t+1}+d_t\right)+\pi_t=D_{t+1}+c_t+s_{t+1}p_{t+1}, \tag{3.2.1}$$

where $\beta \in]0,1[$ is the discount factor and E_t is the expectation operator.

The first order conditions with respect to D_{t+1} and s_{t+1}, are given by

$$\beta E_t\left(1+r_{t+1}\right)=1, \tag{3.2.2}$$

$$p_{t+1}=\beta E_t\left(d_{t+1}+p_{t+2}\right). \tag{3.2.3}$$

The combination of (3.2.2) and (3.2.3) gives the households no arbitrage condition, $E_t\left(d_{t+1}+p_{t+2}\right)/p_{t+1}=E_t\left(1+r_{t+1}\right)$. This last condition states that the return on stocks is equal to the return on deposits. If it is met, households are indifferent between both types of assets and both are held in the portfolio of agents. However, if this condition is not satisfied, the optimal solution of households yields to a corner solution, thus, only stocks or only deposits are held, depending on which has the highest return.

Since the optimization problem has an infinite horizon, consider also the transversality condition:

$$lim_{t\to\infty}\beta^t p_t s_t=0. \tag{3.2.4}$$

Condition (3.2.4) ensures that the household spends all its budget and thus, does not hold positive wealth when $t \to \infty$. It is a necessary condition for an optimum choice of the household. Tirole (1982) shows that bubbles under rational expectations with infinitely lived agents cannot exist since the transversality cannot be satisfied. However, in our framework, banking bubbles satisfy this condition and therefore, may exist.

3.2.2. Firms

Firms are represented by a continuum of identical producers of unit mass. Each firm starts with an amount of loans L_0 to buy its initial capital K_0. Firms are subject to productivity shocks. The shock process is defined by an AR(1) process such that $A_t = A_{t-1}^{z_A} \exp(u_t)$, where z_A is a strictly positive persistence parameter and u_t is a normally distributed productivity shock with mean 0 and variance σ_z^2. After the shock, in each period t, firms produce y_t using capital K_t bought in the last period and reimburse their loans with interests r_t^l such that the total reimbursement is $L_t\left(1+r_t^l\right)$. Then, they distribute net profits to households and choose their optimal amount of total loans and capital for the next period $\{L_{t+1}, K_{t+1}\}_{t=0}^{\infty}$ to maximize their future expected discounted profits subject to their budget constraint (3.2.5) and the capital constraint (3.2.6). Note that we consider capital that fully depreciates. Each firm optimization problem is defined as follows:

$$Max_{\{L_{t+1},K_{t+1}\}_{t=0}^{\infty}} E_t \sum_{t=0}^{\infty} \beta^t \pi_t,$$

subject to

$$\pi_t = y_t - L_t\left(1+r_t^l\right), \tag{3.2.5}$$

$$y_t = A_t K_t^{\psi},$$

$$K_{t+1} = L_{t+1}, \tag{3.2.6}$$

$$\pi_t \geq 0 \text{ and } L_t, K_t > 0,$$

where $\psi \in]0,1[$ is the output elasticity of capital. Using the Lagrange method, the interior solution of the first order condition with respect to L_{t+1} is given by:

$$\psi E_t\left(A_{t+1} L_{t+1}^{\psi-1}\right) = E_t\left(1+r_{t+1}^l\right). \tag{3.2.7}$$

In the optimum, (3.2.7) shows that the marginal product of capital is equal to the marginal cost of loans.

3.2.3. Banks

The banking sector is represented by a continuum of identical banks of unit mass. To provide loans L_{t+1} to firms, banks raise funds by accumulating net worth N_{t+1} and demanding deposits D_{t+1}. The regulatory authority imposes that banks keep a fraction $\phi \in [0,1[$ of deposits as reserves[6]

[6]Note that the reserve requirement ϕ is not crucial for the model nor for the bubble existence. However, it is of interest as it allows the derivation of additional policy implications.

$$R_t \equiv \phi D_t. \tag{3.2.8}$$

Each bank has a balance sheet composed of deposit D_t and net worth N_t on the liability side and of loans L_t and reserves R_t on the asset side such that

$$R_t + L_t = N_t + D_t. \tag{3.2.9}$$

Thus, at the end of each period t, each bank accumulates net worth using profits from assets earned in t net of deposit repayments and dividends. Let r_t^l be the lending rate earned in t and r_t the risk-free interest rate paid in t, so that

$$N_{t+1} = \left(1 + r_t^l\right) L_t + R_t - D_t \left(1 + r_t\right) - d_t - \mathbb{C}_t, \tag{3.2.10}$$

where $\mathbb{C}_t = \tau N_t$ represents operational costs paid by banks such as accounting and legal fees and management costs. The parameter $\tau \in]0, 1]$ is the share of operational costs in net worth. One can think about initial public offering fees paid to a third party, for example to a business attorney or business service companies, to get listed on financial markets. Indeed, banks often use a third party such as large business service companies (KPMG, Deloitte) to prepare the legal and accounting side of public offerings. Specialized firms ensure that regulatory and legal compliance are met.

Banks are also subject to capital requirements based on Value-at-Risk as recommended by the Basel committee in Basel II.[7] This regulation imposes that banks hold a minimum level off capital which is calculated with the aim of avoiding banks becoming insolvent. The objective of the regulator is to preserve a safety buffer, such that the market value of banks' assets VA_t is sufficient to repay depositors. The market value of assets is given by

$$\mathrm{VA}_t = V_t\left(N_t\right) + D_t,$$

where $V_t\left(N_t\right)$ is banks' equity value. Therefore, the regulator imposes a solvency condition which requires that the maximum amount of deposits banks can hold does not exceed the market value of banks assets in the worst case scenario such that

$$D_t \leq \left(1 - \mu\right) \mathrm{VA}_t,$$

[7]See the BIS publication, the First Pillar Minimum Capital Requirements, http://www.bis.org/publ/bcbs107.htm

where $\mu \in [0,1[$ is a regulatory parameter which captures the loss in market value of assets in the worst case scenario, as motivated by the Value-at-Risk regulation. This regulation, based on market values, is the same as in Dangl and Lehar (2004). The above equation is thus equivalent to

$$D_t \leq \eta V_t(N_t),$$

where $\eta = (1-\mu)/\mu > 0$ is the Value-at-Risk regulation parameter. It represents the maximum allowed leverage ratio in market value. We show in Appendix A that without capital requirements, if

$$\tau\beta(1-\phi) > \phi(1-\beta), \tag{3.2.11}$$

banks always hold the maximum amount of deposits. Indeed, when the marginal benefit from holding deposits exceeds its marginal cost, banks always want more deposits. From now on, we consider that (3.2.11) is always satisfied. Therefore, the above constraint always binds and becomes

$$D_t = \eta V_t(N_t). \tag{3.2.12}$$

For low values of η, the regulation is severe. Indeed, the amount of authorized deposits that banks can hold compared to banks' value is low. However, for high η, the regulation is considered as lenient.

The aim of our framework is to model the existence of stochastic banking bubbles as in Blanchard and Watson (1982), Weil (1987) and Miao and Wang (2015). In period t, agents may believe in a bubble or not. If agents do not believe a banking bubble exists in period t, a bubble can never emerge. In what follows, first, we present the problem of banks when agents do not believe a bubble exists. We then present the problem of banks when agents believe that it exists. In this latter case, following Blanchard and Watson (1982), we consider that the bubble may burst in the future with a probability $\xi \in]0,1[$. Note that once the bubble bursts, it never reappears.

Bubbleless path

At the end of period t, each bank chooses its optimal net worth to accumulate for next period $\{N_{t+1}\}$ in order to maximize its current dividends and expected present value of future dividends subject to the reserve requirement (3.2.8), the balance sheet (3.2.9), the budget constraint (3.2.10) and the capital requirement (3.2.12). If agents do not believe a bubble exists, the value of the bank in period t is denoted $V_t^*(N_t)$. The bank problem can be summarized by the following Bellman equation:

$$V_t^*(N_t) = Max_{\{N_{t+1}\}} \left\{ d_t + \beta E_t \left[V_{t+1}^*(N_{t+1}) \right] \right\},$$

subject to

$$d_t = \left(1 + r_t^l\right) N_t + D_t \left[r_t^l(1-\phi) - r_t \right] - \tau N_t - N_{t+1}, \tag{3.2.13}$$

$$D_t = \eta V_t^*(N_t), \tag{3.2.14}$$

$$N_t, D_t \geq 0 \text{ for all } t. \tag{3.2.15}$$

We show in Appendix B that the solution of the above maximization problem gives us the following form for the value function:

$$V_t^*(N_t) = q_t^* N_t, \tag{3.2.16}$$

where $q_t^* \geq 0$ is the marginal value of net worth. It can also be interpreted as the Tobin Q (Tobin, 1969). Define the bank's stock price in $t+1$ by

$$p_{t+1} = \beta E_t \left[V_{t+1}^*(N_{t+1}) \right].$$

Proposition 1. *When agents do not believe a bubble exists, the solution of each bank maximization problem is given by the following system of equations.*

$$\begin{aligned} E_t\left(q_{t+1}^*\right) &= \frac{1}{\beta}, & (3.2.17) \\ q_t^* &= \left(1 + r_t^l - \tau\right) + \eta q_t^* \left[r_t^l (1-\phi) - r_t \right]. & (3.2.18) \end{aligned}$$

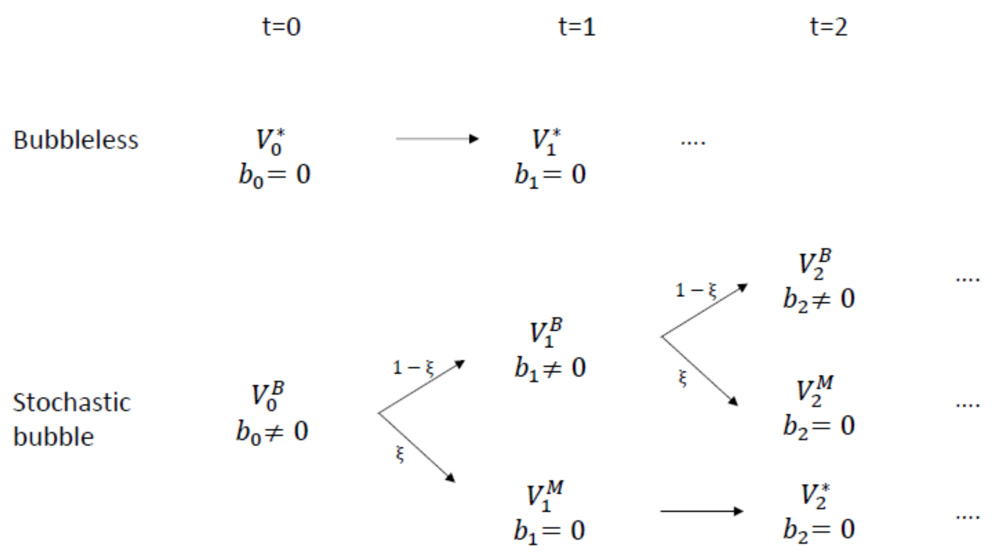
Proof of Proposition 1 is presented in Appendix B.

When agents do not believe a bubble exists, the expected marginal value of net worth given by (3.2.17) is constant. This comes from the fact the bank is risk-neutral. Thus, by increasing one unit of net worth today, the bank gets the expected discounted marginal value of net worth. Equation (3.2.18) shows that an additional unit of net worth today gives the discounted return due to the increase in loans minus operational costs. It also allows the bank to relax the constraint by taking η units of additional deposits (see equation (3.2.12)). Then, the bank earns an additional return of $\left[r_t^l(1-\phi)-r_t\right]$. Using (3.2.17) and (3.2.18), results show that the lending rate is also constant, which is consistent with the risk neutrality assumption.

Bubbly path

When agents believe that a bubble exists in period t, the bank's value $V_t^B(N_t)$ contains a bubble $b_t \neq 0$. There exists a probability $\xi \in]0,1[$ that the bubble bursts in $t+1$ such that $b_{t+1}=0$ and thus, that the bank's value becomes $V_{t+1}^M(N_{t+1})$. Note that following Blanchard and Watson (1982), we assume that once the bubble bursts, it never reappears. Therefore, the bank's value can take two different possible values in $t+1$: $V_{t+1}^B(N_{t+1})$ or $V_{t+1}^M(N_{t+1})$, which occur, respectively, with a probability $(1-\xi)$ and ξ. The timeline of events of the bubble and the value function are summarized in Figure 3.2.3.1.

Figure 3.2.3.1. – Timeline of events



When a banking bubble exists in t, each bank chooses the optimal net worth $\{N_{t+1}\}$ in order to maximize its current dividends and expected present value of future dividends subject to the reserve requirement (3.2.8), the balance sheet

(3.2.9), the budget constraint (3.2.10) and capital requirements (3.2.12).

$$V_t^B(N_t) = Max_{\{N_{t+1}\}} \left\{ d_t + \beta E_t \left[V_{t+1}^B(N_{t+1}) \right] + \xi \beta E_t \left[V_{t+1}^M(N_{t+1}) - V_{t+1}^B(N_{t+1}) \right] \right\}, \tag{3.2.19}$$

subject to

$$d_t = \left(1 + r_t^l\right) N_t + D_t \left[r_t^l (1-\phi) - r_t \right] - \tau N_t - N_{t+1}, \tag{3.2.20}$$

$$D_t = \eta V_t^B(N_t), \tag{3.2.21}$$

$$N_t, D_t \geq 0 \quad \text{for all } t, \tag{3.2.22}$$

where $V_{t+1}^M(N_{t+1})$ is the value of the bank if the bubble bursts in $t+1$ and is defined by $V_{t+1}^*(N_{t+1})$ in the bubbleless equilibrium. Note that the difference between $V_{t+1}^M(N_{t+1})$ and $V_{t+1}^*(N_{t+1})$ lies in their initial values of net worth. The last term of (3.2.19) represents the change in values when the bubble bursts. Indeed, when the bubble bursts with a probability of ξ, the banks value shifts from $V_{t+1}^B(N_{t+1})$ to $V_{t+1}^M(N_{t+1})$.

We show in Appendix C that the solution of the bank maximization problem with a bubble gives the following value function, until the bubble bursts:

$$V_t^B(N_t) = q_t^B N_t + b_t, \tag{3.2.23}$$

where $q_t^B \geq 0$ is the marginal value of net worth and $b_t \neq 0$ is the bubble term on the bank's value. Variables q_t^B and b_t are to be endogenously determined. As it will become clear later, the bubble term is a self-fulfilling component that can be increasing, decreasing or explosive. Note that (3.2.23) is the same as in Miao et al. (2013). Define the stock price in $t+1$ when agents believe a bubble exists and before the bubble bursts by

$$p_{t+1} = \beta E_t \left[V_{t+1}^B(N_{t+1}) \right] + \xi \beta E_t \left[V_{t+1}^M(N_{t+1}) - V_{t+1}^B(N_{t+1}) \right].$$

Proposition 2. *When agents believe a bubble exists in t, until the bubble bursts, the solution of each bank maximization problem is given by the following system* *of equations.*

$$\begin{aligned} E_t\left(q_{t+1}^B\right) &= \frac{1-\xi\beta E_t\left(q_{t+1}^M\right)}{\beta\left(1-\xi\right)}, && (3.2.24)\\ q_t^B &= \left(1+r_t^l-\tau\right)+\eta q_t^B\left[r_t^l\left(1-\phi\right)-r_t\right], && (3.2.25)\\ (1-\xi)\beta E_t\left(b_{t+1}\right) &= b_t\left\{1-\eta\left[r_t^l\left(1-\phi\right)-r_t\right]\right\}. && (3.2.26) \end{aligned}$$

From the regulation based on Value-at-Risk, the regulator forces the bank to satisfy (3.2.12) such that if $b_{t+1}=0$*, the value of* q_{t+1}^M *is given by*

$$q_{t+1}^M=\frac{1}{\eta}\frac{D_{t+1}}{N_{t+1}}. \tag{3.2.27}$$

Proof of Proposition 2 is presented in Appendix C.

Equation (3.2.24) shows that, by increasing one unit of net worth today, the bank gets the expected discounted marginal value of net worth if the bubble lasts plus the expected discounted marginal value of net worth if the bubble bursts. The probability of a burst introduces a price distortion because it changes inter-temporal arbitrage conditions. An increase in the marginal value of net worth if the bubble bursts, decreases the marginal value of net worth if the bubble stays. Therefore, the bank's incentive to accumulate net worth if the bubble remains is reduced, and then, the bank distributes more dividends compared with when $b_t=0$ for all t. Equation (3.2.25) has the same intuition than in the case where $b_t=0$ for all t. However, here, the lending rate is not constant anymore and is positively correlated with the marginal value of net worth. The intuition is that the larger the lending rate is, the larger the incentive for banks to accumulate net worth is.

Equation (3.2.26) exists if and only if agents believe in the bubble such that $b_t\neq 0$. It represents the bubble growth rate. The idea is that the bubble allows the bank to relax the capital requirement constraint by raising the bank's value and thus increases deposits. In particular, the bubble allows to relax the capital requirement constraint while avoiding the operational costs. By increasing additional units of deposits, the growth of the economy becomes larger. Moreover, the larger the marginal gain from the bubble $\eta\left[r_t^l\left(1-\phi\right)-r_t^D\right]$ is, the smaller the growth rate of the bubble is. Finally, the bubble grows faster with ξ to compensate for the probability of bursting.

Proposition 3. *If*

$$\left\{1-\eta\left[r_t^l(1-\phi)-r_t\right]\right\}/\beta(1-\xi)<1/\beta, \tag{3.2.28}$$

the transversality condition of the household (3.2.4) is always satisfied.

Proof of Proposition 3 is presented in Appendix D.

Proposition 3 states that the transversality condition (TVC) is satisfied, i.e bubbles are not ruled out, if the growth rate of the bubble does not exceed the rate of time preference of households. The transversality condition insures that individuals do not hold positive wealth when $t \to \infty$. An important point to highlight here, is that without the capital requirement constraint the bubble growth is given by $E_t(b_{t+1})/b_t - 1 = 1/[\beta(1-\xi)] - 1$, which is ruled out by the TVC. Therefore, the bubble cannot exist. In addition, the combination of (3.2.24), (3.2.25) and (3.2.26) yield $E_t(b_{t+1})/b_t - 1 = \left(1+r_t^l-\tau\right)/\left(1-\beta\xi q_t^M\right)$. Thus, the growth rate is larger than $1/\beta$ when $\tau = 0$, which is ruled out by the TVC. The intuition is that operational costs ($\tau > 0$) reduce the growth rate of net worth and then, by no arbitrage, the growth rate of the bubble. Therefore the bubble is no longer explosive and is not ruled out. Analogously, Miao and Wang (2015) reduce the growth of net worth by assuming a minimum dividend policy as a function of net worth. It is also straightforward that under regulation based on book values as in Basel I, instead of on market values such that with the Value-at-Risk, bubbles cannot exist.[8]

The bubble return can be written as:

$$b_t\left(\frac{1}{\beta}-1\right)=\underbrace{\frac{1}{\beta(1-\xi)}\left\{\eta\left[r_t^l(1-\phi)-r_t\right]-\xi\right\}b_t}_{\text{dividend yield}}+\underbrace{E_t(b_{t+1})-b_t}_{\text{capital gain}}. \tag{3.2.29}$$

This equation shows that the return on the bubble is equal to a capital gain $E_t(b_{t+1}) - b_t$ plus a dividend yield. The dividend yield in the infinite horizon model guarantees that the transversality condition does not rule out the bubble. By relaxing the capital requirement, the bubble allows banks to raise η more units of deposits and earn a return $\left[r_t^l(1-\phi)-r_t\right]$ on it.

[8] The Basel ratio Tier 1 is based on book values and takes the following form: $N_t = \chi D_t$ where $\chi > 0$ is a regulation parameter.

3.3. Bubbleless general equilibrium

This section defines and analyzes the bubbleless general equilibrium where variables are denoted x_t^*.

Definition 4. A competitive general bubbleless equilibrium with $b_t = 0$ for all t, is defined as sequences of allocations, prices and the shock process

$$\mathcal{E}_t^* = \left\{d_t^*, N_{t+1}^*, K_{t+1}^*, L_{t+1}^*, D_{t+1}^*, \pi_t^*, y_t^*, c_t^*, s_{t+1,}^* q_t^*, r_t, r_t^{l*}, p_t^*, A_t\right\} \forall t,$$

such that taking prices as given, all agents maximize their future expected payoffs subject to their constraints and the transversality condition is satisfied. Finally, the market for loans, deposits, and stocks ($s_{t+1}^* = 1$) clear. The equilibrium consumption is given by the combination of the three budget constraints (3.2.1), (3.2.5) and (3.2.10), such that

$$c_t^* + \tau N_t^* = y_t^* - L_{t+1}^* - (R_{t+1}^* - R_t^*). \tag{3.3.1}$$

Equation (3.3.1) is the condition on the goods market. The sum of households and banks consumption $c_t^* + \tau N_t^*$ is equal to output net of investment and variation in reserves. Households' consumption decreases with the investment which is represented by the amount of loans, the reserve variation and operational costs.

Bubbleless stationary equilibrium

Here, we analyze a stationary bubbleless equilibrium when variables are constant over time such that $\mathcal{E}_0^* = ... = \mathcal{E}_t^* = \mathcal{E}^*$ for all t. The equilibrium deposit rate is given by (3.2.2) such that $r = \frac{1}{\beta} - 1$. The marginal value of net worth in (3.2.17) is $q^* = \frac{1}{\beta}$. From the regulation based on Value-at-Risk in (3.2.12) and the value function (3.2.16),

$$\frac{D^*}{N^*} = \frac{\eta}{\beta}. \tag{3.3.2}$$

From (3.2.18), the lending rate is

$$r^{l*} = \frac{r\left(\eta + \beta\right) + \beta\tau}{\beta + \eta\left(1 - \phi\right)}. \tag{3.3.3}$$

Proposition 5. *The lending rate r^{l*} in a bubbleless stationary equilibrium increases with the reserves ϕ and operational costs τ. In contrast, it decreases with the Value-at-Risk regulation parameter η.*

Proof of Proposition 5 is presented in Appendix E. The intuition is that larger operational costs and reserves reduce the supply of loans, and as a consequence increase the lending rate. In contrast, a larger Value-at-Risk regulation parameter η allows banks to raise money using cheaply acquired funds, i.e deposits. This effect raises banks' size and reduces the lending rate.

For more insights, we also look at the interest rate spread, which is given by

$$\beta\left(r^{l*} - r\right) = \frac{(1-\beta)\,\eta}{\beta + \eta\,(1-\phi)}\phi + \frac{\beta^2}{\beta + \eta\,(1-\phi)}\tau.$$

The above equation shows that the discounted interest rate spread increases with operational costs τ and the fraction of reserves ϕ. For $\phi = 0$, the interest spread is only a function of operational costs. When there are no costs for the bank such that $\phi = \tau = 0$, the lending rate falls to the safe rate r.

The stationary level of loans is given by the first order condition (3.2.7) so that $L^* = \left[\left(1 + r^{l*}\right)/\psi\right]^{1/(\psi-1)}$. From the balance sheet constraint (3.2.9) and (3.3.2), $N^* = L^*/\left[1 + (1-\phi)\,(\eta/\beta)\right]$. Thus, the equilibrium consumption is given by $c^* = (L^*)^{\psi} - L^* - \tau L^*/\left[1 + (1-\phi)\,(\eta/\beta)\right]$. Denote W^* the welfare in a bubbleless stationary equilibrium. Therefore, $W^* = c^*$. The Appendix F shows that W^* and L^* are decreasing in the lending rate r^{l*}.

3.4. Stochastic bubbly general equilibrium

This section defines and analyzes the stochastic bubbly general equilibrium where variables before and after the bubble bursts at $t = T$ are, respectively, denoted x_t^B and x_t^M.

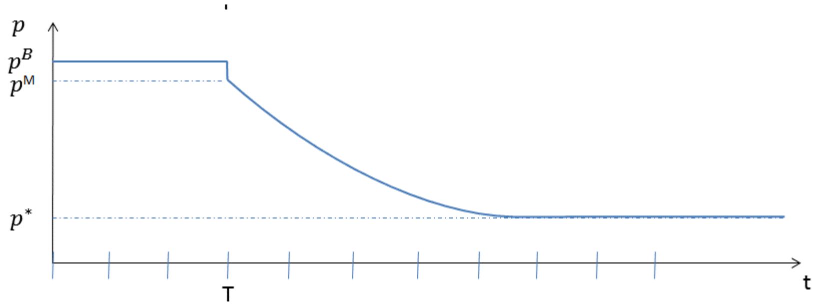
Definition 6. If a bubble exists in t such that $b_t \neq 0$, until the bubble bursts in T, a competitive stochastic bubbly general equilibrium is defined as

$$\mathcal{E}_t^B = \{d_t^B, N_{t+1}^B, K_{t+1}^B, L_{t+1}^B, D_{t+1}^B, \pi_t^B, y_t^B, c_t^B, b_t, s_{t+1,}^B q_t^B, q_t^{MB}, r_t, r_t^{lB}, p_t^B, A_t\}\,\forall t < T,$$

such that taking prices as given, all agents maximize their future expected payoffs subject to their constraints and the transversality condition is satisfied.[9] Finally, the market for loans, deposits, and stocks ($s^B_{t+1} = 1$) clear. At $t = T$, the bubble crashes such that $b_t = 0\ \forall t \geq T$, a competitive stochastic bubbly general equilibrium $\mathcal{E}^M_t$ is defined as $\mathcal{E}^*_t\ \forall t \geq T$ with $N^M_T = N^B_T$, such that taking prices as given, all agents maximize their future expected payoffs subject to their constraints and the transversality condition is satisfied. Finally, the market for loans, deposits, and stocks ($s^M_{t+1} = 1$) clear. As in the bubbleless equilibrium, the condition on the goods market is given by (3.3.1), where variables correspond to the ones from the stochastic bubbly general equilibrium.

For simplicity, as in Weil (1987) and Miao and Wang (2015), we study a stochastic bubbly equilibrium with the following properties. The equilibrium is constant until the bubble collapses at $t = T$, such that $\mathcal{E}^B_0 = ... = \mathcal{E}^B_{T-1} = \mathcal{E}^B$ with $b_0 = ... = b_{T-1} = b \neq 0$. We call it a semi-stationary equilibrium. At $t = T$, the banking bubble collapses such that $b_T = 0$ and the equilibrium is denoted by $\mathcal{E}^M_T$. Then, for all $t > T$, the equilibrium $\mathcal{E}^M_T$ converges to the bubbleless stationary equilibrium $\mathcal{E}^*$. Figure 3.4.0.1 shows the dynamic of the price when a positive banking bubble exists and then bursts.

Figure 3.4.0.1. – Stock price's dynamic when the positive bubble bursts



At $t = T$, the bubble bursts such that $b_t = 0$ and stays at this value for all $t \geq T$. The price p^B_t falls to p^M_T. Then, the bank maximizes dividends and expected discounted future dividends such that the bubble is over and will never reappear. Therefore, the price converges to p^* for all $t > T$.

The semi-stationary equilibrium, i.e until the bubble bursts, is characterized by the following values. As in the bubbleless stationary equilibrium, the deposit

[9]Note that the bank marginal value of net worth q^B_t until the bubble bursts is a function of the marginal marginal value of net worth after the bubble collapses q^M_t. Therefore, this latter value is included in the equilibrium before the burst of the bubble and is called q^{MB}_t.

rate is given by (3.2.2) $r = \frac{1}{\beta} - 1$. The lending rate before the bubble collapses is defined by (3.2.26) such that

$$r^{lB} = \frac{r(\beta + \eta) + \beta\xi}{(1-\phi)\,\eta}. \tag{3.4.1}$$

Proposition 7. *In a semi-stationary bubbly equilibrium, the lending rate increases with the reserves ϕ and the probability of burst ξ. In contrast, it decreases with the Value-at-Risk regulation parameter η.*

Compared to the bubbleless lending rate given by (3.3.3), the lending rate is independent of operational costs τ. This characteristic will be explained later.

The interest rate spread between the lending rate and the risk-free deposit rate, until the bubble collapses, is

$$\beta\left(r^{lB} - r\right) = \frac{1-\beta}{(1-\phi)}\phi + \frac{\beta\,(1-\beta)}{(1-\phi)}\frac{1}{\eta} + \frac{\beta^2}{(1-\phi)}\frac{\xi}{\eta}.$$

Hence, the spread is a function of the bank's costs. It is increasing with a large probability of burst to compensate for the risk and with high fraction of reserves ϕ. In contrast, it decreases with less stringent capital requirement, which is represented by a high η. If $\xi = \phi = 0$, then the interest rate spread is is equal to $\beta\,(1-\beta)\,/\eta$, which is proportional to the tightness of the regulatory constraint.

The marginal value of net worth while the bubble lasts and when the bubble collapses are, respectively, given by (3.2.24)

$$q^B = \frac{1 - \beta\xi q^M}{\beta(1-\xi)} = \frac{1 - \tau + r^{lB}}{\beta(1-\xi)}, \tag{3.4.2}$$

and

$$q^{MB} = \frac{\tau - r^{lB}}{\beta\xi}. \tag{3.4.3}$$

From (3.2.27), the leverage ratio is

$$\frac{D^B}{N^B} = \eta q^{MB}. \tag{3.4.4}$$

From the first order condition of firms (3.2.7), we obtain the equilibrium quantity of loans

$$L^B = \left[\frac{1}{\psi} \left(1 + r^{lB} \right) \right]^{\frac{1}{\psi - 1}}. \tag{3.4.5}$$

From (3.2.8), (3.2.9), (3.4.4) and (3.4.5),

$$N^B = \frac{L^B}{1 + (1 - \phi)\, \eta q^{MB}}.$$

It can be shown that N^B is strictly positive if and only if $q^{MB} > 0$ which is equivalent to

$$\tau > \left[r(\beta + \eta) + \beta \xi \right] / \left(1 - \phi \right) \eta. \tag{3.4.6}$$

Equation (3.4.6) is called the "non negative net worth condition". In what follows, we consider that this condition always holds. From the regulation (3.2.12) and the value function when the bubble exists (3.2.23),

$$b = \frac{D^B}{\eta} - q^B N^B. \tag{3.4.7}$$

Using (3.4.2), (3.4.4) and (3.4.7), the bubble term can be re-written as

$$\begin{aligned} b &= \left(q^{MB} - q^B \right) N^B \\ &= \left[\frac{\eta \left(\tau - \xi \right) \left(1 - \phi \right) - r \left(\eta + \beta \right) + \beta \xi)}{\beta \xi (1 - \xi) \left(1 - \phi \right) \eta} \right] N^B. \end{aligned} \tag{3.4.8}$$

The equation above shows that the bubble increases with large operational costs. An increase in operational costs τ should, without bubble, raise the lending rate. However, in the presence of a bubble, the increase in τ enlarges the bubble, which relaxes the capital requirement constraint. Thus, loan supply increases, canceling out the effect of τ on the lending rate. From (3.2.12) and (3.2.1), the equilibrium consumption is $c^B = \left(L^B \right)^{\psi} - L^B - \tau L^B / \left[1 + (1 - \phi) D^B / N^B \right]$. Finally, we define the bubbly semi-stationary welfare as $W^B = c^B$. Compared to the bubbleless stationary equilibria, the welfare has the same form. However, it now depends on the bubble. Indeed, the bubble modifies the value of lending rate by affecting the capital requirement constraint and thus, the equilibrium quantity of loans. The stationary bubbleless and the semi-stationary stochastic bubbly equilibrium are compared in the next section.

Using (3.4.8), the condition under which a semi-stationary stochastic bubbly equilibrium exists can be written as $\xi \neq \bar{\xi}$, where

$$\bar{\xi} = \frac{\eta\left[(1-\phi)\tau - r\right] - (1-\beta)}{\beta + \eta(1-\phi)}. \tag{3.4.9}$$

Therefore, the semi-stationary stochastic bubbly equilibrium exists if the probability of burst is $\xi \neq \bar{\xi}$. It can be shown that a positive bubble exists for small values of the probability of burst, $\xi < \bar{\xi}$. This is consistent with Weil (1987) and Miao and Wang (2015) who also find that positive bubbles exist only for small values of the bursting probability. Suppose the bubble is positive. Hence, a change in beliefs concerning the probability of burst might modify the equilibrium, from a positive semi-stationary bubbly equilibrium to a bubbleless stationary equilibrium.

Figure 3.4.0.2. – Bubble's value in the parameter space

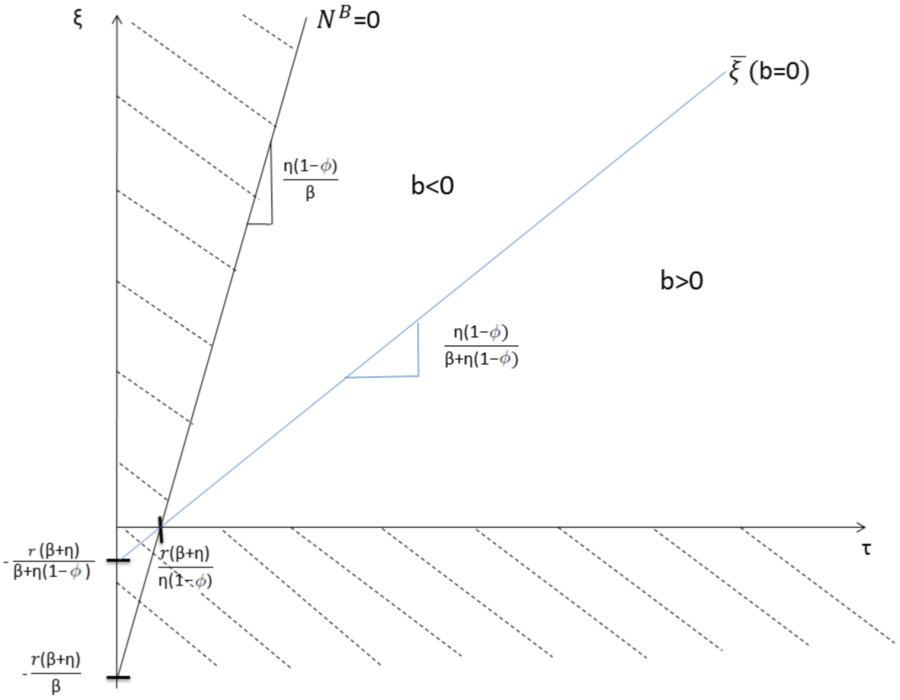


Figure 3.4.0.2 displays the bubble's value in the parameter space (ξ,τ), for a given η and ϕ. At $\xi = \bar{\xi}$, the bubble term is zero. For $\xi < \bar{\xi}$ (resp. $\xi > \bar{\xi}$), the bubble is positive (resp.negative). The slope of the line $\bar{\xi}$ increases with large values of the Value-at-Risk regulation parameter η. Thus, the parameter space for the positive bubble widens. As the regulator becomes more lenient such that η is high, the economy can enter a state in which bubbles are

positive, increasing welfare in the economy. As explained above, the space where $\xi > [\tau(1-\phi)\eta - r(\beta+\eta)]/\beta$ does not exist as $N^B > 0$.

Alternatively, we can also write the existence condition of a stochastic semi-stationary bubbly equilibrium in terms of the regulation parameter based on Value-at-Risk η such that $\eta \neq \bar{\eta}$, where

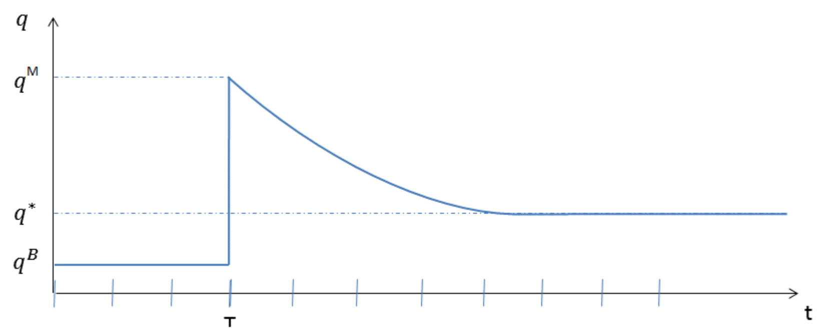
$$\bar{\eta} = \frac{1-\beta(1-\xi)}{(\tau-\xi)(1-\phi)-r}.$$

Proposition 8. *Under (3.2.11), (3.2.28), (3.4.6) and $\eta \neq \bar{\eta}$, a stochastic semi-stationary bubbly equilibrium exists ($b \neq 0$). For $\eta > \bar{\eta}$, the bubble is positive. In contrast, for $\eta < \bar{\eta}$, it is negative.*

Proposition 8 suggests that the semi-stationary equilibrium with a stochastic bubble exists if the regulation parameter based on Value-at-Risk is $\eta \neq \bar{\eta}$. Indeed, under the conditions described in Proposition 8, the transversality condition is satisfied. As a result, a positive bubble exists only for large values of the regulation parameter η. Thus, a reduction of the regulation parameter η might modify the equilibrium, from the positive bubbly equilibrium to the bubbleless equilibrium. Another important policy implication, here, is that the reserve requirement parameter ϕ affects negatively the threshold $\bar{\eta}$. As a consequence, when ϕ is large, the regulation parameter η should be even greater for the economy to be in the positive bubbly semi-stationary equilibrium.

Figure 3.4.0.3 shows the dynamics of the positive stochastic bubbly equilibrium for the marginal value of net worth q_t, before and after the bubble bursts at $t = T$. Suppose $b_t > 0$ for all $t < T$.

Figure 3.4.0.3. – Transition path when the positive bubble bursts



At $t = T$, the bubble bursts such that $b_t = 0$ and stays at this value for all $t \geq T$. Since deposits and net worth are pre-determined variables, from (3.2.27), the marginal value of net worth q^B goes straight to q_T^M. Thus, the value of the bank and the price become, respectively, $V_T^M(N_T^B)$ and p_T^M. Then, the bank maximizes dividends and expected discounted future dividends such that the bubble is over and will never reappear. Therefore, the bank net worth converges from N_T^B to the net worth value in the stationary bubbleless equilibrium N^* on the path N_t^M and the marginal value from q_t^M to the bubbleless stationary equilibrium marginal value of net worth q^*. Thus, the price p_t^M converges to p^* for all $t > T$.

3.5. Comparison of both equilibria

This section compares the stationary bubbleless and the stochastic semi-stationary bubbly equilibria.

Proposition 9. *If $\eta \neq \bar{\eta}$ both equilibria with and without a bubble on stock prices exist.*

Proposition 10. *If $\eta > \bar{\eta}$, the bubbly equilibrium lending rate before that the bubble collapses is lower than the bubbleless lending rate. Thus, welfare is larger with a positive bubble. In contrast, a negative bubble ($\eta < \bar{\eta}$) reduces welfare.*

Proof of Proposition 10 is in Appendix G. Both stochastic bubbly and bubbleless equilibria co-exist for all values of the Value-at-Risk regulation parameter η except at the point $\bar{\eta}$. This point can be viewed as a point of reversal at which you may move from a positive bubbly equilibrium to a negative bubbly stochastic semi-stationary equilibrium. At this reversal point, the equilibrium can move from from higher to lower welfare. For $\eta > \bar{\eta}$, the capital requirement based on Value-at-Risk is less stringent. In that case, the stochastic semi-stationary bubbly equilibrium provides larger welfare than the bubbleless equilibrium. The intuition is that, when agents consider that the bubble exists, a lower capital requirement leads to optimistic beliefs on banks value. The bubble allows banks to relax the capital requirement constraint, and thus banks demand more deposits, which raises their leverage, and make more loans. This effect reduces the lending rate and provides better welfare. In contrast, for more stringent capital requirement $\eta < \bar{\eta}$, the bubble is negative leading to a credit crunch and thus, reducing the welfare compared to the bubbleless equilibrium. An important point to highlight here is that a change in banking regulation may modify the equilibrium and leads to crises, by reducing welfare levels. This effect can explain the occurrence of crises without any external shocks. In addition, using (3.4.9), results also show that a change in beliefs about the probability of burst may also lead to a crisis, as in Miao and Wang (2015).

The following table summarizes and compares the main results discussed in this section.

Table 3.5.0.1. – Policy implication

	$\eta > \bar{\eta}$	$\eta < \bar{\eta}$
variables		
b	$b>0$	$b<0$
r^l	$r^{lB} < r^{l*}$	$r^{lB} > r^{l*}$
L	$L^B > L^*$	$L^B < L^*$
$\frac{D}{N}$	$\frac{D^B}{N^B} > \frac{D^*}{N^*}$	$\frac{D^B}{N^B} < \frac{D^*}{N^*}$
W	$W^B > W^*$	$W^B < W^*$

Table 3.5.0.1 shows that, when agents believe a bubble exists, a positive bubble arises for lenient regulatory Value-at-Risk constraints, $\eta > \bar{\eta}$. It leads to the highest equilibrium welfare level, highest equilibrium quantity of loans and leverage levels. On the opposite, a negative bubble arises when capital requirement based on Value-at-Risk are more stringent. The negative bubbly semi-stationary equilibrium is characterized by the lowest equilibrium level of welfare, credit and leverage.

3.6. Local dynamics and simulations

The present section, first, presents the calibration. Second, it analyzes local dynamics around the bubbleless stationary equilibrium and the semi-stationary stochastic bubbly equilibrium. Finally, we simulate and compare a negative productivity shock from both equilibria.

3.6.1. Calibration

Here, we calibrate the parameters and we report the implied values for variables in the bubbleless stationary and bubbly semi-stationary equilibria. We present a numerical example. We calibrate the discount factor $\beta = 0.99$, the capital share $\psi = 0.33$, the probability of burst $\xi = 0.1$. The regulatory parameter is $\mu = 0.09$, which implies that $\eta = 10.11$. This calibration for μ allows us to have a tier 1 ratio around 8% as recommended by the Basel committee.[10] This ratio is 8.99% for the bubbleless stationary equilibrium and 7.12% for the semi-stationary stochastic bubbly equilibrium. The reserve parameter $\phi = 0.01$ is set as required by the European Central Bank.[11] Finally, we set operational costs to a proportion $\tau = 0.15$ of net worth. Under these values of parameters, Propositions 9 and 10 show that the bubbly and the bubbleless stationary equilibria, until the bubble bursts, exist and that the stochastic bubbly semi-stationary equilibria has a positive bubble ($\eta > \bar{\eta}$). Moreover, under this calibration, the marginal value of net worth in T, once the bubble has burst is $q_T^M = 1.3021$.

Table 3.6.1.1. – Bubbleless and bubbly equilibria

	Bubbly > 0	Bubbleless
Variables		
N	0.0132024	0.0166121
D	0.173818	0.169664
d	0.000171925	0.000167799
L	0.185282	0.184579
p	0.0170206	0.0166121
q	0.977657	1.0101
r^l	0.0210922	0.0236939
b	0.00428355	0
W	0.386042	0.385514

Table 3.6.1.1 confirms results summarized in Table 3.5.0.1. Compared to the bubbleless steady state, the quantity of loans supplied by banks is larger in the stochastic bubbly semi-stationary equilibrium. This gives a relatively lower lending rate r^l, leading to a higher welfare W.

[10]This ratio is defined as total net worth over risky assets.

[11]See https://www.ecb.europa.eu/mopo/implement/mr/html/calc.en.html.

3.6.2. Local dynamics

To analyze the stability and uniqueness properties of the system, we log-linearize the system around the stationary and the semi-stationary equilibria. This results in a system of stochastic linear difference equations under rational expectations. When agents do not believe a bubble exists, $b_t = 0$ for all t, as well as when agents believe a bubble exists, $b_t > 0$ for $t = 0, ...T$, until the bubble bursts, the eigenvalues associated with the linearized system around, respectively, the stationary bubbleless and the stochastic semi-stationary bubbly equilibria, show that the number of unstable eigenvalues (eigenvalues that lie outside the unit circle) is equal to the number of forward looking variables.[12] Thus, under this calibration, the system of equations when $b_t = 0$ for all t and when $b_t > 0$ for all $t < T$, is determined and both the bubbleless and the bubbly equilibria are stable and unique. This implies that given an initial value of N_t^* in the neighborhood of the stationary bubbleless equilibrium, there exists a unique value of q_t^* such that the system of linear difference equations converges to the unique stationary bubbleless equilibrium along a unique saddle path (see Blanchard and Kahn, 1980). Similarly, given an initial value of N_t^B in the neighborhood of the stochastic semi-stationary bubbly equilibrium, there exists a unique value of q_t^B such that the system of linear difference equations converges to the unique stochastic semi-stationary bubbly equilibrium along a unique saddle path, for all $t < T$.

3.6.3. Simulations

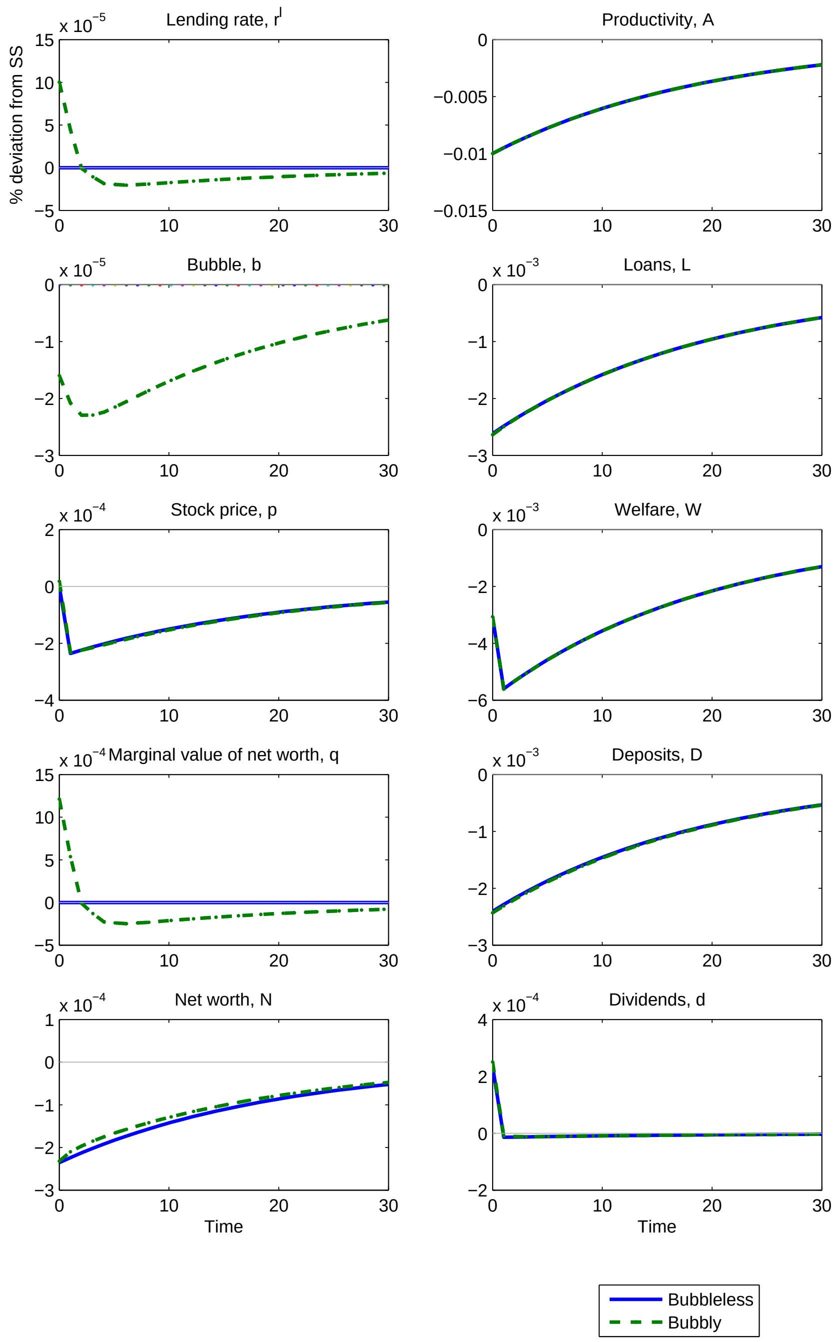
As an illustration, Figure 3.6.3.1 displays the impulse response functions of a 1% negative productivity shock from the stationary bubbleless and the semi-stationary positive stochastic bubbly equilibria until the bubble bursts (for all $t < T$). To that end, we calibrate the persistence of the productivity shock z_A to 0.95. This is standard in the real business cycle literature.

From the bubbleless stationary equilibrium, a negative productivity shock decreases firms profits and thus also the demand for loans. By the balance sheet, the reduction in assets of banks leads to a fall in net worth accumulation, which increases dividends (see equation (3.2.10)). Moreover, the fall in net worth reduces the ability of banks to raise deposits. The reduction in loans

[12]Eigenvalues are reported in Appendix H.

leads to a decrease in production and welfare. Since there is no uncertainty about the bank's value, the marginal value of net worth and the lending rate are constant. Finally, the stock price falls following the decrease in net worth.

Figure 3.6.3.1. – Negative productivity shock



The impulse response functions from the semi-stationary stochastic bubbly equilibrium are similar to the ones from the bubbleless equilibrium. The main difference lies in the fact that the uncertainty on the burst of the bubble changes the inter-temporal substitution between net worth and dividends. A negative productivity shock that decreases loans demand and decreases net worth raises the marginal value of net worth. Indeed, a fall of net worth below its steady state value raises the incentive to increase net worth, reducing the value of holding investment in the bubble, and thus the bubble growth diminishes. Therefore, net worth from the bubbly equilibrium falls by less than from the bubbleless equilibrium.

In conclusion, impulse response functions from both equilibria show that the effect of a productivity shock are similar. This suggests that the bubble does not amplify the effect of shocks on real economic variables.

3.7. Conclusion

In this study, we develop a stochastic general equilibrium model in infinite horizon with a regulated banking sector where a stochastic banking bubble may arise endogenously. We show that a bubble emerges if agents believe that it exists. Thus, expectations of agents are self-fulfilling. Results suggest that when banks face capital requirements based on Value-at-Risk, two different equilibria emerge and can exist: the bubbleless and the bubbly equilibria. Capital requirements based on Value-at-Risk allow the bubble to exist. Alternatively, under a regulatory framework where capital requirements are based on credit risk only as specified in Basel I, a bubble is explosive and as a consequence cannot exist. The stochastic bubbly equilibrium is characterized by a positive or a negative bubble depending on capital requirements based on Value-at-Risk. We find a maximum capital requirement under which the bubble is positive. Below this threshold, the stochastic bubbly equilibrium provides larger welfare than the bubbleless equilibrium. Therefore, this result suggests that a change in banking policies might lead to a crisis. This can explain the existence of crises without any external shocks. We also show that a semi-stationary equilibrium with a positive (resp. negative) stochastic bubble exists if the probability that the bubble collapses is small (resp. high). Consequently, a change in beliefs about the bubble's probability of burst also modifies the equilibrium, from a higher to a lower welfare.

Our model can be extended by the addition of different elements. Risk aversion of households and endogenous labor choice can be considered. However, endogenous labor choice will complicate the model without changing our main results. Risk aversion can be introduced by a quadratic utility function for households and thus, the emergence of bubbles can be studied in this context. One can also add a probability of default on loans repayments in order to model credit risk in the economy and analyze its impact on key macroeconomic variables.

3.8. Appendices

3.8.A. Appendix A

Here, we show that without capital requirement, each bank chooses to hold the maximum amount of deposits.
Each bank maximization problem without capital requirement is given by

$$V_t\left(N_t, D_t\right) = Max_{\{N_{t+1}, D_{t+1}\}}\left[d_t + \beta E_t V_{t+1}(N_{t+1}, D_{t+1})\right],$$

subject to

$$d_t = \left(1 + r_t^l\right) N_t + D_t\left[r_t^l(1-\phi) - r_t\right] - \tau N_t - N_{t+1},$$

$$N_t, D_t \geq 0 \quad \text{for all } t.$$

From the problem described above,

$$\begin{aligned} V_t(N_t, D_t) = & \\ & Max_{\{N_{t+1}, D_{t+1}\}}\left\{\left(1 + r_t^l\right) N_t + D_t\left[r_t^l\left(1-\phi\right) - r_t\right] - \tau N_t \right. . \\ & \left. - N_{t+1} + \beta E_t V_{t+1}(N_{t+1}, D_{t+1})\right. \end{aligned} \tag{3.8.1}$$

equation The marginal value from an increase in net worth and deposits are given by

$$\frac{\partial V_t\left(N_t, D_t\right)}{\partial N_{t+1}} = -1 + \beta E_t \frac{\partial V_{t+1}(N_{t+1}, D_{t+1})}{\partial N_{t+1}}, \tag{3.8.2}$$

and

$$\frac{\partial V_t\left(N_t, D_t\right)}{\partial D_{t+1}} = \beta E_t \frac{\partial V_{t+1}(N_{t+1}, D_{t+1})}{\partial D_{t+1}}.$$

Using the envelop theorem,

$$\frac{\partial V_t\left(N_t, D_t\right)}{\partial N_t} = 1 + r_t^l - \tau,$$

and

$$\frac{\partial V_t\left(N_t, D_t\right)}{\partial D_t} = r_t^l\left(1-\phi\right) - r_t.$$

Banks decide to hold an infinite amount of deposits if $\partial V_t\left(N_t, D_t\right)/\partial D_{t+1} > 0$, which is equivalent to

$$r_t^l\left(1-\phi\right) - r_t > 0. \tag{3.8.3}$$

The interior solution for the net worth is given by $\partial V_t(N_t, D_t)/\partial N_{t+1} = 0$. Equation (3.8.2) becomes

$$1 + r_t^l - \tau = \frac{1}{\beta}. \tag{3.8.4}$$

From equation (3.8.4), we get the following lending rate

$$r_t^l = \frac{1}{\beta} - 1 + \tau.$$

Putting (3.8.2) in (3.8.3), we get the following condition

$$\tau\beta(1-\phi) > \phi(1-\beta).$$

If the above condition holds, banks always choose the maximum amount of deposits, and consequently the capital requirement regulation always binds.

3.8.B. Appendix B

This appendix presents the proof of Proposition 1. From the bank bubbleless maximization problem,

$$V_t^*(N_t) = Max_{\{N_{t+1}\}}\left\{d_t + \beta E_t\left[V_{t+1}^*(N_{t+1})\right]\right\},$$

subject to

$$d_t = \left(1 + r_t^l\right)N_t + D_t\left[r_t^l(1-\phi) - r_t\right] - \tau N_t - N_{t+1},$$

$$D_t = \eta V_t^*(N_t),$$

$$N_t, D_t \geq 0 \ \text{ for all } t.$$

The Bellman equation becomes

$$V_t^*(N_t) = Max_{\{N_{t+1}\}}\left(1 + r_t^l - \tau\right)N_t + \eta V_t(N_t)\left[r_t^l(1-\phi) - r_t\right] - N_{t+1} + \beta E_t\left[V_{t+1}^*(N_{t+1})\right].$$

The marginal value from a net worth increase is given by

$$E_t\left[\frac{\partial V_t^*(N_t)}{\partial N_{t+1}}\right] = -1 + \beta E_t\left[\frac{\partial V_{t+1}^*(N_{t+1})}{\partial N_{t+1}}\right].$$

By the envelop theorem,

$$\frac{\partial V_t^*(N_t)}{\partial N_t} = \left(1 + r_t^l - \tau\right) + \eta \frac{\partial V_t^*(N_t)}{\partial N_t} \left[r_t^l (1-\phi) - r_t\right].$$

The interior solution for the net worth is given by $\partial V_t(N_t)/\partial N_{t+1} = 0$. Therefore,

$$E_t\left[\frac{\partial V_{t+1}^*(N_{t+1})}{\partial N_{t+1}}\right] = \frac{1}{\beta}.$$

Since the problem is linear in N, we get

$$V_t^*(N_t) = q_t^* N_t. \tag{3.8.5}$$

Replacing (3.8.5) in the maximization problem, the solution is given by the following system:

$$\begin{aligned} E_t\left(q_{t+1}^*\right) &= \frac{1}{\beta}, \\ q_t &= \left(1 + r_t^l - \tau\right) + \eta q_t \left[r_t^l (1-\phi) - r_t\right]. \end{aligned}$$

3.8.C. Appendix C

This appendix proves Proposition 2. From the bank maximization problem when agents believe in a bubble such that $b_t \neq 0$, we have

$$V_t^B(N_t) = Max_{\{N_{t+1}\}}\left\{d_t + \beta E_t\left[V_{t+1}^B(N_{t+1})\right] + \xi\beta\left\{E_t\left[V_{t+1}^M(N_{t+1})\right] - E_t\left[V_{t+1}^B(N_{t+1})\right]\right\}\right\},$$

subject to

$$d_t = \left(1 + r_t^l\right) N_t + D_t\left[r_t^l(1-\phi) - r_t\right] - \tau N_t - N_{t+1},$$

$$D_t = \eta V_t^B(N_t),$$

$$N_t, D_t \geq 0 \text{ for all } t,$$

where $V_{t+1}^M(N_{t+1})$ is the value of the bank if the bubble bursts in $t+1$ and is defined as $V_{t+1}^*(N_{t+1})$ for the bubbleless maximization problem.

The Bellman equation becomes

$$V_t^B(N_t) = Max_{\{N_{t+1}\}}\left\{\left(1 + r_t^l - \tau\right) N_t + \eta V_t(N_t)\left[r_t^l(1-\phi) - r_t\right] - N_{t+1}\right\}.$$

The marginal value from a net worth increase is given by

$$E_t\left[\frac{\partial V_t^B(N_t)}{\partial N_{t+1}}\right] = -1+\beta E_t\left[\frac{\partial V_{t+1}^B(N_{t+1})}{\partial N_{t+1}}\right] + \xi\beta E_t\left[\frac{\partial V_{t+1}^M(N_{t+1})}{\partial N_{t+1}} - \frac{\partial V_{t+1}^B(N_{t+1})}{\partial N_{t+1}}\right].$$

By the envelop theorem,

$$\frac{\partial V_t^B(N_t)}{\partial N_t} = \left(1+r_t^l-\tau\right)+\eta\frac{\partial V_t^B(N_t)}{\partial N_t}\left[r_t^l(1-\phi)-r_t\right].$$

The interior solution for the net worth is given by $\partial V_t^B(N_t)/\partial N_{t+1} = 0$. Therefore,

$$E_t\left[\frac{\partial V_{t+1}^B(N_{t+1})}{\partial N_{t+1}}\right] = \frac{1-\xi\beta E_t\left[\frac{\partial V_{t+1}^M(N_{t+1})}{\partial N_{t+1}}\right]}{(1-\xi)\beta}.$$

Since the problem is linear in N, we get

$$V_t^B(N_t) = q_t^B N_t + b_t. \tag{3.8.6}$$

Replacing (3.8.6) in the maximization problem, the solution is given by the following system:

$$\begin{aligned} E_t\left(q_{t+1}^B\right) &= \frac{1-\xi\beta E_t\left(q_{t+1}^M\right)}{\beta(1-\xi)}, \\ q_t^B &= \left(1+r_t^l-\tau\right)+\eta q_t^B\left[r_t^l(1-\phi)-r_t\right], \\ (1-\xi)\beta E_t(b_{t+1}) &= b_t\left\{1-\eta\left[r_t^l(1-\phi)-r_t\right]\right\}. \end{aligned}$$

3.8.D. Appendix D

This appendix presents the proof of Proposition 3. We show the condition to ensure that the stochastic bubbly equilibrium until the bubble bursts satisfies the transversality condition. The following transversality condition is required:

$$lim_{t\to\infty} p_t\beta^t = lim_{t\to\infty} E_{t-1}\left[\xi\left(q_t^M N_t\right)+(1-\xi)\left(q_t^B N_t + b_t\right)\right]\beta^t = 0.$$

It is satisfied if

$$lim_{t\to\infty} E_{t-1}\left[\xi\left(q_t^M N_t\right)+(1-\xi)N_t q_t^B\right]\beta^t = lim_{t\to\infty} E_{t-1}(1-\xi)\, b_t\beta^t = 0.$$

Since the bubble growth rate is

$$\frac{E_t\left(b_{t+1}\right)}{b_t}=\frac{1}{\beta\left(1-\xi\right)}\left\{1-\eta\left[r_t^l\left(1-\phi\right)-r_t\right]\right\},$$

the TVC requires that

$$\frac{1}{\beta\left(1-\xi\right)}\left\{1-\eta\left[r_t^l\left(1-\phi\right)-r_t\right]\right\}<\frac{1}{\beta}.$$

Thus, the condition to allow a bubble to exist is

$$\eta\left[r_t^l\left(1-\phi\right)-r_t\right]>\xi.$$

3.8.E. Appendix E

This appendix proves Proposition 5. Here, we prove that the interest rate of loans in the bubbleless stationary equilibrium is negatively correlated with the Value-at-Risk regulation parameter η. Using (3.3.3), we have that

$$r^{l*}=\frac{r\left(\eta+\beta\right)+\beta\tau}{\beta+\eta\left(1-\phi\right)}.$$

Therefore,

$$\frac{\partial r^{l*}}{\partial\eta}=\frac{\left(1-\beta\right)-\left[1-\beta\left(1-\tau\right)\right]\left(1-\phi\right)}{\left[\beta+\eta\left(1-\phi\right)\right]^2}<0.$$

The numerator is negative if and only if $\tau\beta(1-\phi)>\phi\left(1-\beta\right)$, which is always satisfied (see Appendix A).

3.8.F. Appendix F

The stationary bubbleless steady state welfare is given by the consumption such that

$$W=L^{\psi}-\left(1+\frac{\tau}{1+\left(1-\phi\right)\frac{D}{N}}\right)L.$$

Therefore, the marginal impact of the lending rate on welfare is

$$\frac{dW}{dr^l}=\psi\frac{dL}{dr^l}L^{\psi-1}-\frac{dL}{dr^l}\left(1+\frac{\tau}{1+\left(1-\phi\right)\frac{D}{N}}\right).$$

Thus, $\frac{dW}{dr^l} < 0$ if and only

$$\psi L^{\psi-1} < \left(1 + \frac{\tau}{1+(1-\phi)\frac{D}{N}}\right). \tag{3.8.7}$$

Since $L = \left[(1+r^l)/\psi\right]^{\frac{1}{\psi-1}}$,

$$r^l > \frac{\tau}{1+(1-\phi)\,\frac{D}{N}}. \tag{3.8.8}$$

In the stationary bubbleless equilibrium, the lending rate is $r^{l*} = \frac{r(\eta+\beta)+\beta\tau}{\beta+\eta(1-\phi)}$. Therefore the condition (3.8.8) becomes

$$r^{l*} = \frac{r\,(\eta+\beta)+\beta\tau}{\beta+\eta\,(1-\phi)} > \frac{\tau}{\beta+(1-\phi)\,\eta}.$$

It is equivalent to

$$r\,(\eta+\beta) > 0.$$

which is always verified.

3.8.G. Appendix G

Here, we display the proof of Proposition 10. The spread between the bubbly and the bubbleless lending rate is

$$r^{lB} - r^{l*} = \frac{r\eta + 1 - \beta(1-\xi)}{\eta(1-\phi)} - \frac{1-\beta\,(1-\tau)+\eta r}{\beta+\eta\,(1-\phi)}.$$

Therefore, $r^{lB} - r^{l*} > 0$ if

$$\eta < \frac{1-\beta(1-\xi)}{(\tau-\xi)\,(1-\phi)-r} = \bar{\eta}.$$

Hence, the bubbly lending rate is higher than then bubbleless lending rate if and only if a negative bubble exists. For a positive bubble, we have $r^{lB} - r^{l*} < 0$.

As a consequence, it can be shown that the welfare is higher in the presence of a positive bubble. In contrast, it is lower with a negative bubble.

3.8.H. Appendix H

Table 3.8.H.1 displays eigenvalues associated with the linearized system around the stationary bubbleless and the semi-stationary bubbly equilibrium.

Table 3.8.H.1. – Eigenvalues of the bubbly and bubbleless equilibria

bubbly ($b_t > 0$)	bubbleless ($b_t = 0$)
values	values
0	0
0	$2.236 * 10^{-55}$
0	$3.012 * 10^{-36}$
0	$3.452 * 10^{-36}$
$1.456 * 10^{-19}$	$4.408 * 10^{-19}$
$9.661 * 10^{-18}$	$1.321 * 10^{-17}$
$9.161 * 10^{-17}$	$1.472 * 10^{-17}$
0.95	0.95
1.01	1.01
1.038	$1.915 * 10^{39}$
∞	∞
∞	∞
∞	

The computation of eigenvalues are given by Dynare.

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